TECHNOLOGY

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REVIEW

November 1951

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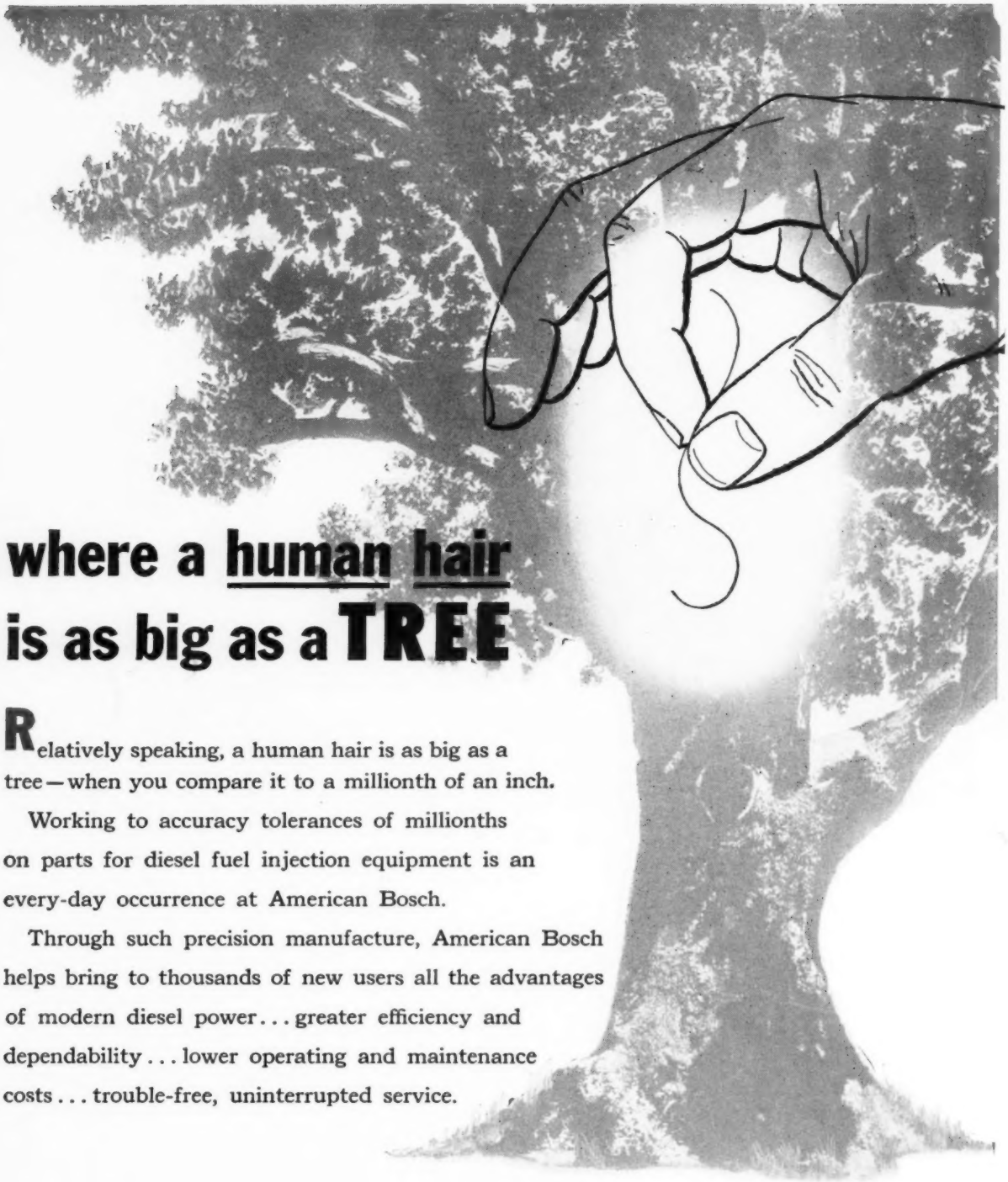

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The tricycle? No! It, too, depends on both Behr-Manning and Norton abrasives for grinding and polishing each component. The hardwood floor, too, is sanded with Behr-Manning abrasive drum covers and discs.

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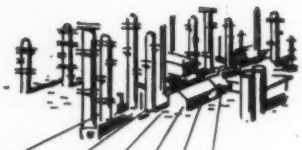
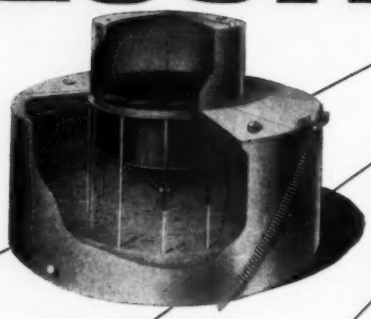
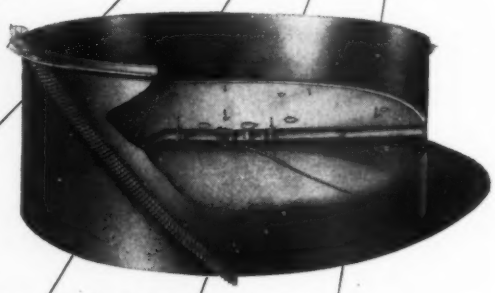
GRAVER

EXCLUSIVES

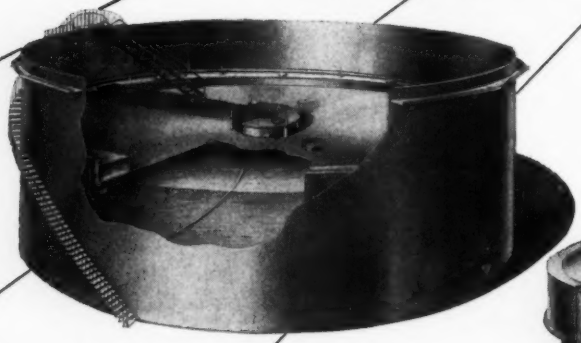




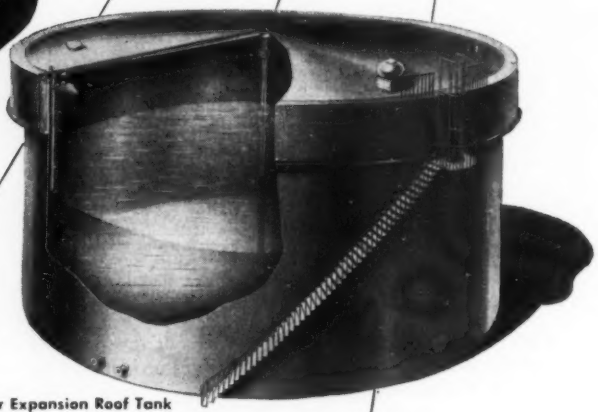
• Graver Vapor-Mizer



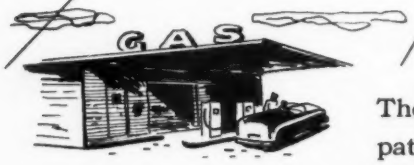
• Graver Double Deck Floating Roof Tank



• Graver Center-Weighted Floating Roof Tank



• Graver Expansion Roof Tank



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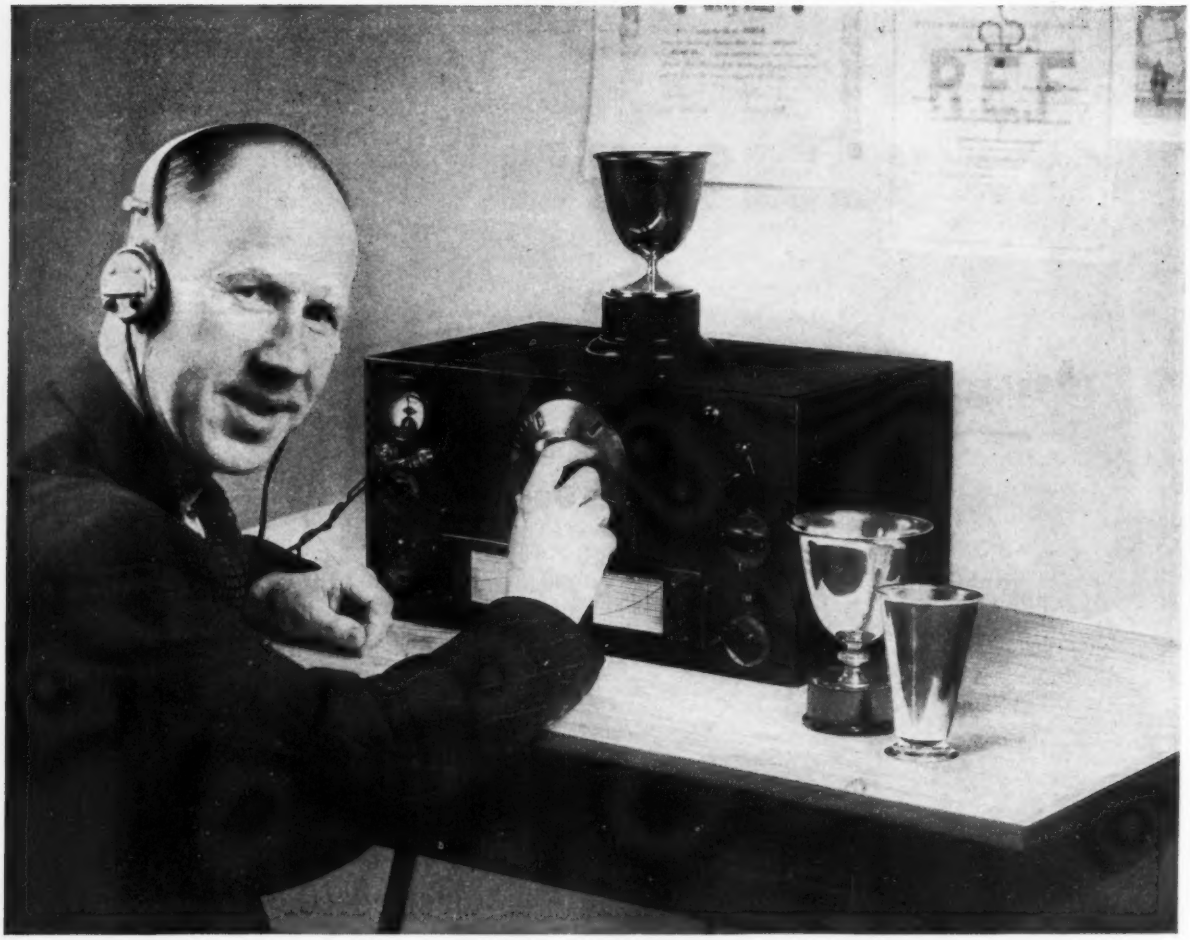

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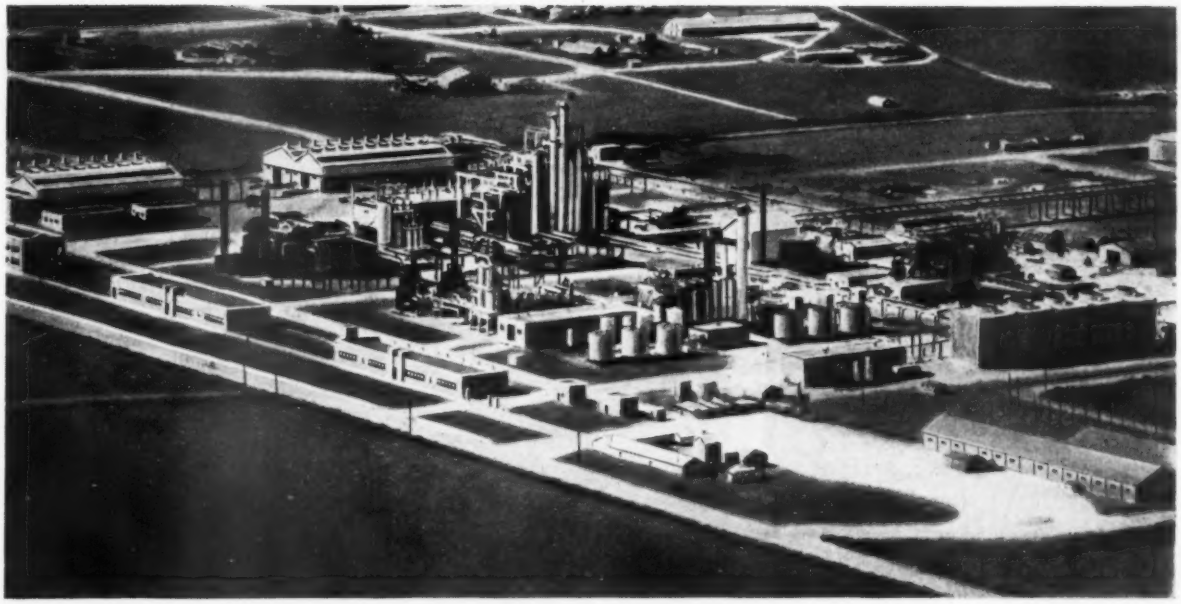

Overall View showing new facilities . . . Ethylene Plant, Ethanol Plant and Isopropanol Plant

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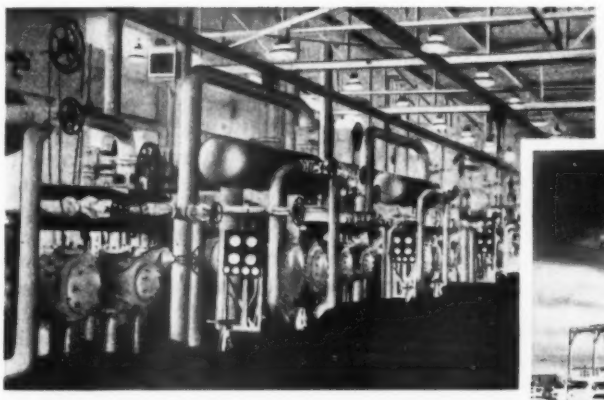
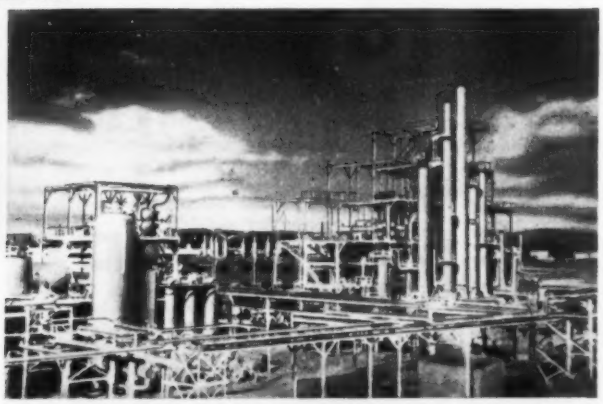


Compressor House — Interior

ETHYLENE PLANT
Cracking and Fractionating Structures



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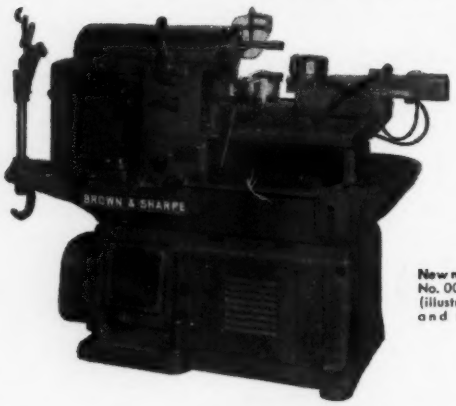

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THE TABULAR VIEW

Riverbank Neighbors. — PRESIDENT KILLIAN'S byline in the pages of The Review is always a happy event; the pleasure is doubled when his name is associated with the first story to open a new volume. In the "Good Neighbor Policy in Cambridge" (page 17), Technology's president takes a look up the Charles River to comment on the good feeling and wholehearted co-operation which exist between the "venerable and comprehensive" Harvard University and her downstream "young and specialized" neighbor on Research Row. The heated debates of an earlier decade were evidently recalled as but dim memories late last spring when Dr. Killian's article made its first bow as the address of the guest of honor at a dinner meeting of the Harvard Club of Boston.

Natural Flight. — With obvious intent to stimulate unconventional thinking about the design of aircraft, JAMES L. G. FITZPATRICK presents an extensive survey of aviation literature in "Some Thoughts on Natural Flight" (page 21). A native of New York City, where he received his bachelor's and master's degrees from Manhattan College in 1930 and 1931, respectively, Mr. FitzPatrick is general assistant of the Textile Evening High School in New York City. He holds a pilot's license and is proprietor of the FitzPatrick Company, which engages in transportation research. A close student of the literature of aviation, Mr. FitzPatrick spends many a busy hour at the library of the Institute of the Aeronautical Sciences. It was there that he came under the watchful eye of S. Paul Johnston, '21, director of that organization, to whom The Review is indebted for suggesting that Mr. FitzPatrick make a bow to Review readers.

Steel Progress. — No commodity is a better yardstick of a nation's industrial activity than steel. With unprecedented demands just ahead for military and civilian use, the nation's capacity to produce steel is undergoing substantial expansion, and the center of gravity of the industry's productive capacity is shifting toward the eastern part of the United States. Recent progress in this fast-moving field is reported in "The Basic Metal" (page 25) by PAUL COHEN, '35, a frequent contributor and an editorial associate of The Review for more than a decade. In his student days, Mr. Cohen was editor of *The Tech*, and subsequently became instructor in the Department of English and History. For a number of years, Mr. Cohen was an engineer with the United Shoe Machinery Corporation. For the past few years his engineering and administrative abilities have been used to advance the interests of the Sperry Gyroscope Company.

Physicist's Phylon. — How well is the Institute fulfilling its mission in training students of physics? For the years 1934 to 1942, the record has been examined by PROFESSOR PHILIP M. MORSE who finds

(Concluded on page 8)

Thinking of improving

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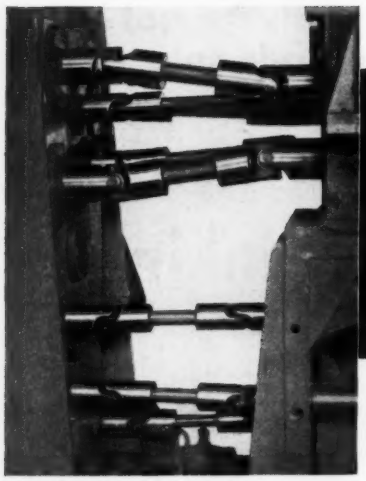

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THE TABULAR VIEW

(Concluded from page 6)

(page 29) that M.I.T. has contributed a disproportionately large share of physicists whose outstanding achievements are recorded in *American Men of Science*. In his article, "Graduate Students in Physics," Dr. Morse also hints that the record for the 1941–1951 decade may be even more impressive. Professor Morse has been a member of the Institute's Department of Physics since 1931, although his residence in Cambridge has been punctuated by leaves of absence to serve the nation elsewhere. In 1946, Dr. Morse became the first director of the Brookhaven National Laboratory, and in 1949 he was appointed research director and deputy director of the Weapons Evaluation Group of the National Military Establishment.

MAIL RETURNS

Memorial Concert

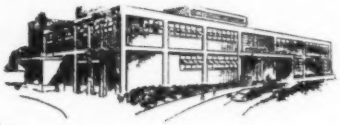
FROM MRS. DOROTHY C. REMICK:

Possibly some of the readers of The Review, especially those who may have been students at the Institute in the twenties and early thirties, may be interested to learn that a memorial concert is to be given for Stephen S. Townsend, Director of Choral Music at M.I.T. from 1924 to 1932. The concert will be held in Recital Hall, College of Music Building, Boston University, at 8:15 P.M. on Monday, December 3, and I understand that the program will consist largely of Mr. Townsend's compositions.

The concert will be open to the public, and all friends, former students, and pupils of my uncle's voice-training classes are cordially invited to attend.

If you find you will have space in your next issue for notice of this event, publication announcement will be greatly appreciated by all who are interested in the success of this memorial concert.

Malden, Mass.



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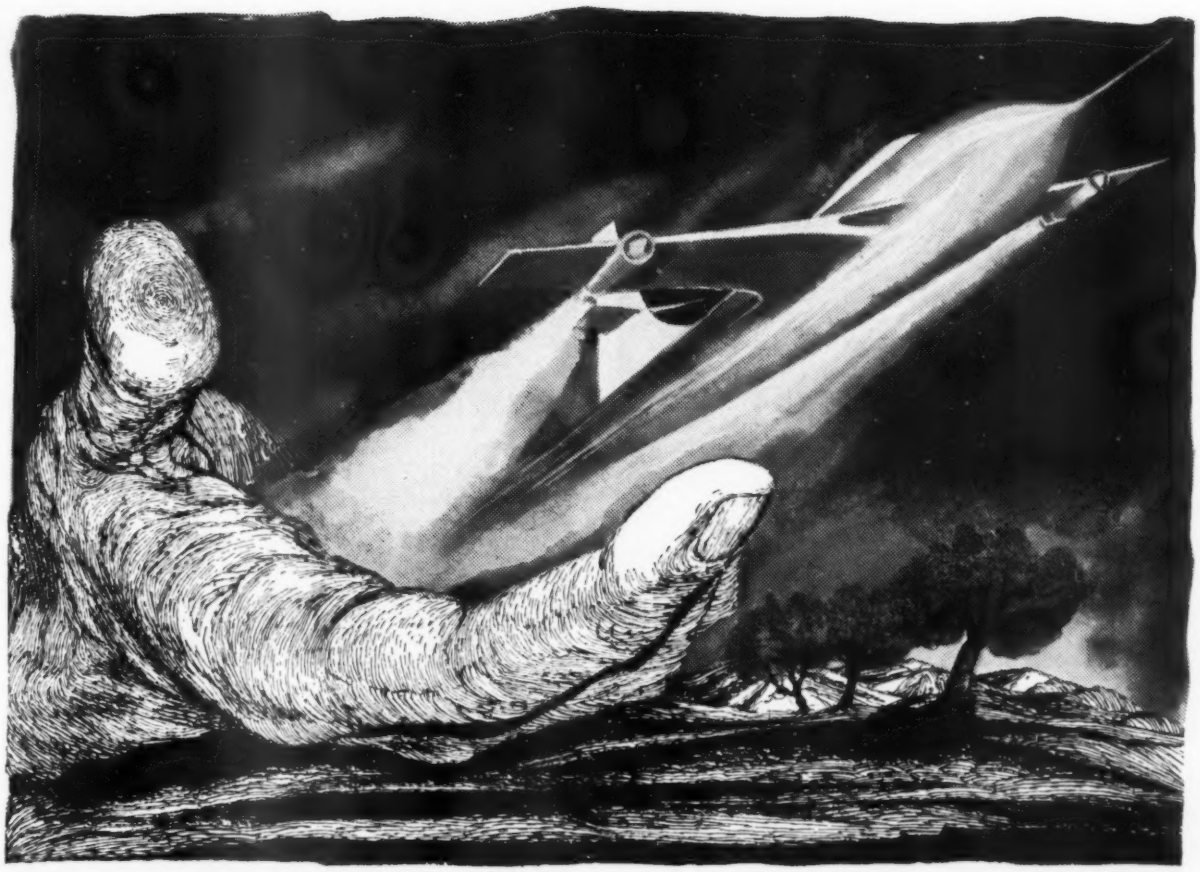

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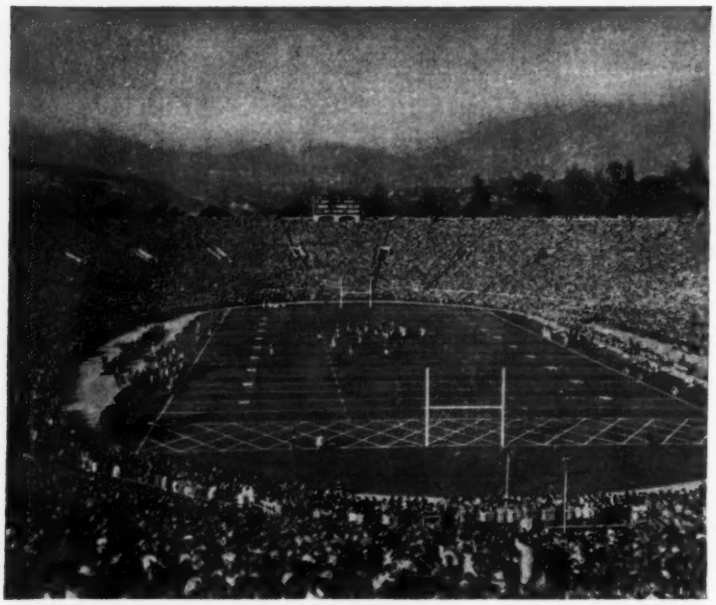

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THE TECHNOLOGY REVIEW

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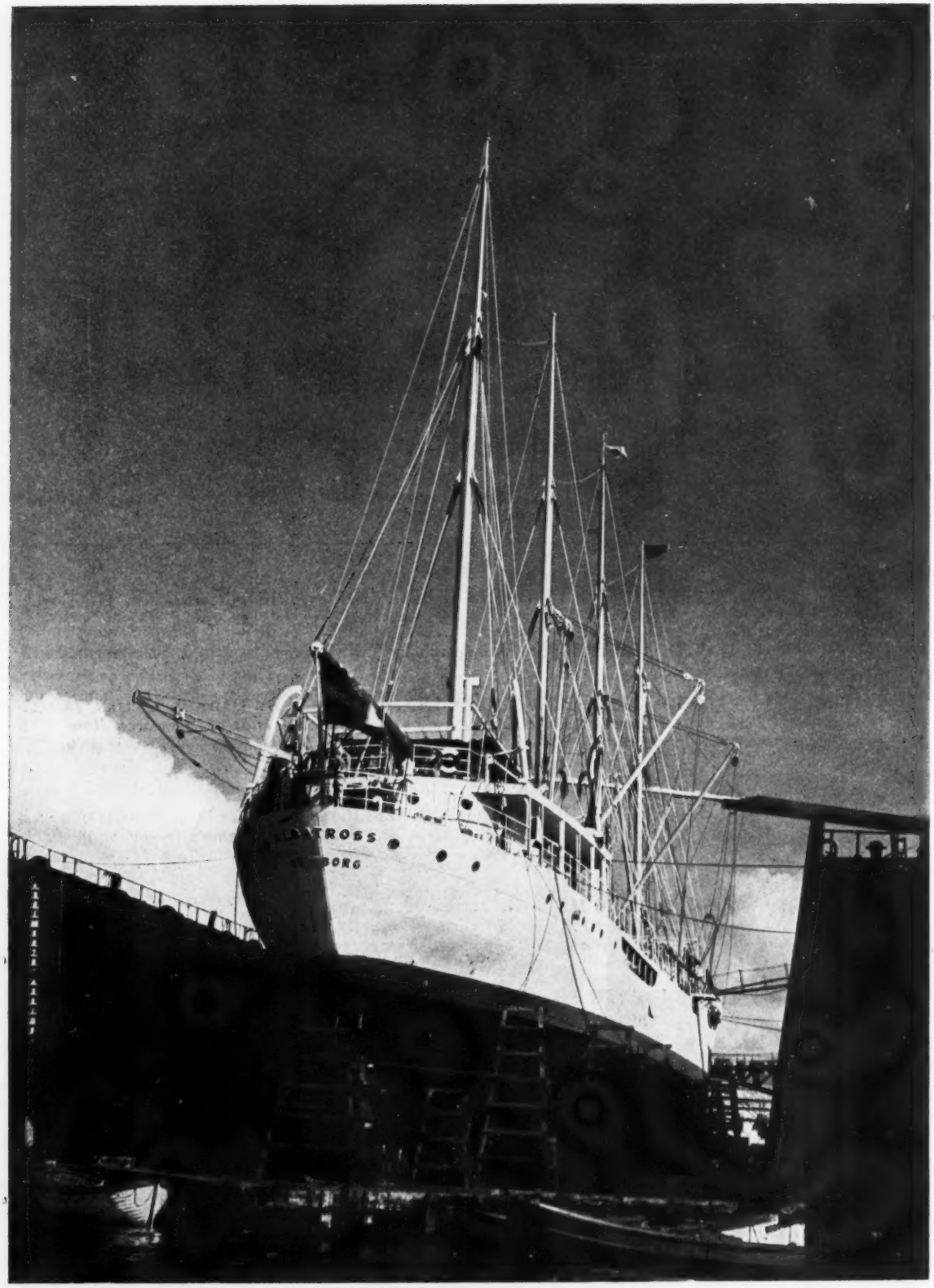


C. E. Patch, '09

"We shall sail securely . . ."

— Henry Wadsworth Longfellow

THE
TECHNOLOGY REVIEW

Vol. 54, No. 1 November, 1951

The Trend of Affairs

Wool Extenders

USING as a probe its merciless demands for more production, the current defense program has revealed one weak spot after another in our raw material situation. For a while, as wool prices rose to record levels, it appeared that this ancient fiber was in short supply. Basically it seems to be moving toward such a position, although prices have since fallen. American consumption, including that for the military services, is close to four pounds per capita, almost the weight of an average complete fleece. With about one-sixth of the world's population, the United States is currently consuming about a quarter of the world's wool production.

Fundamentally, the problem of wool supply stems from the fact that as the sheep population declines, the world's human population is growing. As sheep are crowded off the range by crops, or by animals more essential to human needs, the trend must continue. In 1940 there were 131,000,000 people in this country and 52,107,000 sheep. In 1951 the United States has 152,000,000 people and about 30,000,000 sheep. Even Australia (where there are 102,558,000 sheep today) had 106,420,000 in 1892, its peak year. In 1940 the world contained an estimated 2,080,000,000 people and 747,000,000 sheep. Ten years later, it contained 130,000,000 more people and 17,000,000 less sheep. World production during the early decades of this century was generally over three billion pounds per year. In recent years it has averaged several hundred million pounds less.

That these trends have not more severely affected the textile industry is due, of course, primarily to the rise of the synthetic fibers. To an increasing extent, the ersatz fibers are also being used as blending agents in wool. With some of the earlier synthetics the substitutes have not always represented a net gain in quality, but an increasing number of fibers are being developed which share some of the warmth properties of wool, blend well with it, and tend to make a fabric which holds its shape better in humid atmospheres. In particular, these are the acrylic fibers, of which Dynel, Orlon, Dacron, and Saran are some of the varieties in the commercial or development stage. An output of about 100,000,000 pounds per year of such fibers, by 1953, is predicted.

Titrations with Phototubes

CHEMICAL analysis by titration always involves some method for the determination of the end point. The possibilities of a hitherto neglected method for this determination — measurement of light absorption — was explored in the Laboratory for Nuclear Science and Engineering by David N. Hume, Associate Professor of Chemistry, and Robert F. Goddu, '51, last year a research fellow in the Department of Chemistry. In this method, titrations are carried out inside a commercial spectrophotometer and the changes in the transmittancy of the solution being titrated are determined at frequent intervals. The method has been shown to be accurate and convenient for a wide variety of chemical analyses. The use of monochromatic light and a sensitive light-detecting system makes it possible to utilize very small, but important, color changes in deeply colored solutions. When ultraviolet or infrared light is employed, it is possible to determine end points by changes completely invisible to the human eye. Because of the high sensitivity of spectrophotometric measurements, it is possible to work with very dilute solutions and very small amounts of material.

Among the more interesting results found in the course of this investigation is the discovery that the method is suited to the accurate determination of

quite low concentrations of weak acids or bases in mixtures. The conventional potentiometric and glass electrode methods do not distinguish at all, for example, between two weak acids with ionization constants not differing by more than sixteenfold, even in fairly concentrated solutions. The photometric titration method, however, may give results accurate to a few per cent with dilute solutions of acids, the ionization constants of which differ only by a factor of 10. Another useful feature of the photometric titration method is that determinations may be carried out as easily in nonaqueous media as in water solutions, whereas the ordinary electrical methods are very difficult to apply except in aqueous solutions. Photometric titration promises to be useful in the solution of quite a number of practical problems, such as the determination of mixtures of weak acids or bases, determination of small amounts of strong acids in weak acids, and determination of weak acids in the presence of strong acids.

Safety in Nuclear Reactors

PRIMARY purpose of present-day atomic piles, or nuclear reactors, such as the new pile at the Brookhaven National Laboratory near Patchogue, Long Island, is the production of neutrons. These elementary particles are needed for such research purposes as experiments on matter to be carried out in the immediate vicinity of the reactor; the production of radioisotopes (chemical twins) for uses remote from the reactor; and the transmutation of uranium into plutonium for military purposes.

Great quantities of heat and copious amounts of penetrating gamma rays are by-products of the nuclear reactions for producing neutrons, and neither of these by-products can be very readily or safely dealt with. The gamma rays which accompany the production of neutrons are similar to x-rays corresponding to several million volts and can easily produce harmful effects. To avoid excessive and destructive internal temperatures in the reactor, to provide the necessary safety to personnel, and, finally, to yield precision in experiments and production processes, the rate of neutron production must be very accurately controlled. The equipment required for measurement and control is not unlike that of a chemical production plant, although the speed of operations, the range of magnitudes to be measured and controlled, and the requirements for ruggedness of operation and safety to personnel pose problems in instrumentation not previously solved.

Instrumentation for control and monitoring of the reactor of the Brookhaven National Laboratory was designed and engineered by the Servomechanisms Laboratory at M.I.T., directed by Professor Gordon S. Brown, '31, of the Department of Electrical Engineering. This project, which employed approximately 50 persons for two years, was under the general supervision of William M. Pease, '42, Assistant Professor of Electrical Engineering. Design and construction of the electronic instrumentation for nuclear measurement and monitoring was directed by Truman S. Gray, '29, Associate Professor of Engineering Electronics at the Institute.

Information regarding the rate of neutron production, the temperature at various internal and external points, and the intensity of gamma rays emanating from the reactor is furnished by various electrical detectors located in and around it. In accordance with this information, control rods are inserted to limit the rate of neutron production.

Safety to personnel and to the equipment is a prime consideration in the design of a reactor installation. A carefully engineered, rapid-acting, automatic-shutdown system, therefore, is an important part of the instrumentation. Failure or an excess of any one of numerous variables causes instant shutdown of the reactor. To minimize false shutdowns, the system has been designed to be rugged and positive in its action. The instrumentation techniques employed mark a new and significant advance in the safety and reliability of control for nuclear reactors.

The two shadow photographs shown here are recent examples of the work of Professor Harold E. Edgerton, '27, of the Department of Electrical Engineering, and his associates at M.I.T. Both have been made with exposures of 0.2 microsecond, using the recently developed magneto-optic shutter.

At left are two superimposed photographs of a No. 6 dynamite cap exploding. The interval between exposures was 10 microseconds.

At the right two superimposed exposures have been made of a black powder squid charge with a 16-microsecond interval between exposures. Note that the sound wave does not travel as far in this case as for the dynamite cap.

From Tape to Contour Cutting

IMPORTANT segments of the machine tool industry have long been engaged in extending the usefulness of machine tools through automatic controls of one type or another. The simpler and more obvious means of automatic machine control have been studied extensively over so long a period of time that further substantial progress along traditional lines may soon reach the point of diminishing returns. The next significant step forward will probably employ servomechanisms in addition to control methods which have been developed to a high degree during the past decade. In fact, under the direction of Professor Gordon S. Brown, '31, of the Department of Electrical Engineering, and William M. Pease, '42, Assistant Professor of Electrical Engineering, the Servomechanisms Laboratory at M.I.T., under the sponsorship of the Air Force, is now engaged in an active program devoted to improving the precision of control of automatic machine tools through techniques not yet finding much application in industry.

Under development at M.I.T. is a contour-shaping machine with a cutting tool whose position is controlled by digital information rather than the dimensions of a model, as used in presently existing automatic machine tools. This digital information, which is related to the desired shape of the metal, is inserted into the machine by means of a punched paper tape, somewhat like the tape used in automatic transmission of teletype messages. The information on the tape is interpreted by the "machine director," which comprises a group of 175 relays and 250 electron tubes. The machine director, in turn, controls the angular positions of three separate servomechanisms. By means of a lead screw arrangement, the angular displacement of the three servomechanisms determines the position of the cutting head in each of three orthogonal directions.

Information for punching the paper tape is obtained from the design specification or drawings for the desired part somewhat as follows: The desired path of the center of the tool as it passes over the work surface is first determined, making an appropriate allowance for the dimensions of the tool. The tool path is then divided into straight segments of any lengths which approximate the desired, generally curved, path within any tolerance specified by the designer. Each straight segment is resolved into three orthogonal components parallel to the ways of the machine tool. The numerical values of these three components are then coded appropriately and punched on the tape together with information as to how much time the machine should use in traversing the segment. Once properly punched, the paper tape provides a compact, permanent control record which may be used at any subsequent time in conjunction with the cutting machine to mill duplicate shapes. Because the coded symbols punched on the tape represent discrete numerical data, the position of the cutting head, instead of being infinitely adjustable, is moved in finite steps of 0.0005 inch each. (As differentiated from infinitely continuous operations, discrete step operations are commonly referred to as digital operations.) A consequence of the digital operation is that the machine does not accumulate any error exceeding one 0.0005-inch step regardless of the number of successive straight segments it traverses.

Directions for contour cutting are coded on the punched paper tape in blocks, each block containing the specification for one segmental path, together with codes which serve checking functions. The blocks of information are fed into the machine director intermittently as needed to keep the metal-cutting operation continuous. The machine director contains two relay registers, one of which controls the machine-tool motions while the other receives information from the punched paper tape. Rapid switching alternates the function of the two registers to provide continuous control of the machine tool.

The control devices which position the three elements of the machine tool are designed in the general pattern of military fire-control servomechanisms. The servomotors are small hydraulic transmissions which rotate lead screws to position the machine elements.

An application for which the machine under development is uniquely suited is that of machining straight-line-generated airfoil surfaces. Other applications include the more conventional tasks of template making, cam making, jig boring, and milling models for tracer-controlled contour-milling machines. The preparation of tapes for the machine will be preceded by large amounts of routine computation, and it is expected that economic considerations will make machine methods mandatory for this computation.

Improving Copper Smelting

QUANTITATIVE measurements of equilibrium conditions for chemical reactions in molten oxide and sulfide solutions, at temperatures of 2,200 degrees F. and above, are being made by a group under the supervision of Reinhardt Schuhmann, Jr., '38, Associate Professor of Process Metallurgy, as part of an investigation of the chemistry of copper smelting. Copper smelting is an old, well-established art, the procedure by which most copper is produced today having been developed largely by empirical methods and with only meager knowledge of the high-temperature physical chemistry involved. Although the process is relatively efficient and economical by present metallurgical standards, the decreasing quality of copper-bearing ores, increasing costs for fuels, labor, and other supplies, and emergency demands for the metal, all contribute to make the fundamental study essential as a basis for further development.

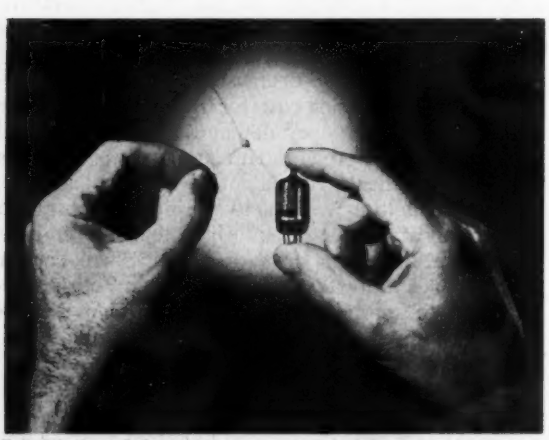
Copper smelting involves two principal steps, both carried out at temperatures so high that the products are molten. In the first or matte smelting step, copper sulfide concentrates and ores are heated with appropriate fluxes to produce a liquid matte (which is a solution of copper and iron sulfides) along with a waste slag consisting of silicon dioxide, iron oxides, and other worthless constituents of the ore. In the second or converting step, the liquid matte is oxidized with air, and fluxes are again added to obtain another iron silicate slag. When the oxidation is completed, the copper remains behind in the converter as a crude metal known as blister copper. This blister copper is subsequently cast and refined electrolytically to the

commercial high-purity copper. Both of the above described steps in making crude copper yield systems containing two reacting liquid phases: a sulfide or matte phase and an oxide-silicate or slag phase.

It is expected that the research program now in progress will afford a quantitative understanding of the reactions and the conditions under which slag losses occur so that it may be possible to devise controls or preventatives. From a long-range point of view, a thorough understanding of the chemistry of mattes, slags, and matte-slag reactions quite possibly will contribute to some radical changes in the smelting procedure as a whole. To date, the laboratory investigations have dealt chiefly with the constitution and chemical properties of iron silicate slags. One of the first problems was to find the ranges of composition and temperature under which the slags exist and to determine also the temperature and composition conditions under which they exist in equilibrium with solid phases, such as magnetite and silica. Since iron is present in the slag, in both ferrous and ferric states, the liquid iron silicates must be regarded as ternary solutions of ferrous oxide, ferric oxide, and silicon dioxide. Therefore, it has been necessary to work out rather completely the constitution of the ternary system at temperatures from 1,200 to 1,400 degrees C. The results show that copper-smelting slags cover a larger range of ferric oxide content than was previously supposed, and that the content of ferric oxide has very significant effects on slag properties. Another feature of the results, which has a direct bearing on the magnetic accretion problem, is the finding that the solubility of magnetite in the slags is quite sensitive to temperature within the usual smelting range.

Revolution in the Making

As a result of research work under the direction of William Shockley, '36, significant advances in the development of a tiny amplifying device, which has been called the first serious rival of the vacuum tube, have been announced during the summer by the Bell Telephone Laboratories. Most important of these advances is the construction of operating samples of a radically new type of amplifying device, called a transistor, which has astonishing properties never before achieved in any amplifying device. Dr. Shockley, who initiated and directed the research leading to the original transistor, predicted the new type more than two years ago, as a result of theoretical studies.



Bell Telephone Laboratories

The spidery object at the left is the newest type of transistor, a tiny amplifying device of rugged construction which requires no heater or filament. For size comparison, note the miniature tube which does about the same job.

In addition to making vast improvements in the performance and uniformity of the original transistor, a radically new and in many ways more effective type of amplifier, called a junction transistor, has been the result of Dr. Shockley's work. Extremely efficient and rugged, the new junction type of transistor is in the form of a small bead, about half the size of a pea. Transistors have been produced which can withstand shock and vibration better than any known vacuum tube and they are expected to have a service life considerably longer than that of commercial vacuum tubes in current use. The transistor can be designed for a great many specific functions, and its range of performance has been extended to include a wide variety of applications which at present require commercial tubes of the well-known vacuum type.

The junction transistor has no point contacts, which in the original transistor corresponded to the terminals of a vacuum tube. Instead, it consists of a tiny rod-shaped piece of germanium, treated so that it embodies a thin, electrically positive layer sandwiched between the two electrically negative ends. The entire rod is encased in a hard plastic bead about three-sixteenths of an inch in diameter, with wire leads connected to each of the three regions and extended outside. This new form of transistor occupies about one four-hundredths of a cubic inch, whereas a typical subminiature vacuum tube occupies about one-eighth of a cubic inch.

Power consumption of this new type of transistor is remarkably low. The signal level often found in modern electronic equipment is about one millionth of a watt. But a full watt of power is ordinarily required by conventional vacuum tubes to amplify this signal. This is about like sending a 12-car freight train, locomotive and all, to carry a pound of butter. The new transistor, unlike any earlier amplifier, can be operated with a power of about a millionth of a watt, which is just sufficient to carry the signal.

Transistors can be operated as amplifiers for telephone and television circuits, and to provide the functions of detection and amplification such as are found in an ordinary radio set. One type also serves as a photoelectric device. These devices are still undergoing exploratory development. While more complete information on the properties which may be achieved will be available after further development, the results to date are encouraging. It is always dangerous to make predictions, but the new devices have such desirable properties and characteristics that they may well cause a revolution in a a wide variety of electronic, communication, and measurement techniques. The transistors do not require power for heating, and therefore can be operated without the delay required for warm-up. The small size, ruggedness, and expected long life of the transistors make them eminently suitable for many applications in which the usual vacuum tubes are not suitable.

Walter R. Fleischer

Good Neighbor Policy in Cambridge

By JAMES R. KILLIAN, JR.

In 1914, A. Lawrence Lowell, Harvard University's President, began an address to an M.I.T. alumni gathering by telling a story appropriate to the relations between Harvard and M.I.T. "I am reminded of the man," he said, "who asked his friend, 'What is the difference between a terrapin and a seraphim?' 'Well, I don't really know,' the friend replied; 'I believe there was a difference at one time, but I understand they have since made it up.'"

That year, 1914, is a significant one in M.I.T.-Harvard history. M.I.T., then in Boston, had decided to move to Cambridge. All talk of a merger of M.I.T. with Harvard had by then been settled in favor of no merger; and the two educational institutions, which were soon to be neighbors in Cambridge, had entered into an arrangement whereby their work in certain fields would be combined. That particular co-operative plan – which I shall refer to again later – was short-lived. But the good-neighbor policy which it inaugurated has continued to this day. I shall venture to review the evolution of this good-neighbor policy.

The story of the M.I.T.-Harvard relationship throughout the years since the Institute's founding is apt in illustrating how "good fences make good neighbors" – even when students sometimes weld the gates shut with thermite. It is also instructive as a case history of how two institutions, one venerable and comprehensive, the other young and specialized, both pre-eminent in their respective fields, have created an environment benign to co-operation. What has been achieved in Cambridge is a commonwealth of scholarship. Two strong, independent, individualistic institutions, vigorously competitive where need be, have forged an intellectual federation which makes Cambridge one of the great centers of learning and research in the world. Even though the two institutions remain jealously independent, they have been creating together a University of Cambridge – an entity which is the more effective because it has no corporate existence except as a willingness to collaborate among a community of scholars.

It is important, I think, to keep in mind that this kind of a relationship does not just happen. Nor is it the kind of association that can be imposed by fiat. It is a relationship which has roots in the past and which has been carefully nurtured. The elements which make it what it is are like those of which Winston Churchill spoke in remarking that the "fraternal association" between the United States and nations of the British Commonwealth is more effective than many associations made through formal alliances. "Peoples of these countries," Churchill said, "know each other particularly well and are old friends . . . their families are intermingled . . . they have faith in each other's purpose, hope in each other's future, and charity towards each other's shortcomings."

Two institutions on the Charles River,
One venerable and comprehensive,
The other young and specialized,
Have created an environment
Benign to co-operation.

What is the history of this fraternal association? It did not open altogether auspiciously. Even before M.I.T. held its first class there was a suggestion that it be joined with Harvard. The Commonwealth had granted M.I.T. a charter on April 10, 1861, on condition that a guaranty fund of $100,000 could be raised within one year. April, 1861, was the month Fort Sumter was fired upon. It was not a good month to start seeking funds for a college; but then, it never seems to be a good moment for that. Because of the Civil War, an extension was granted M.I.T. in obtaining funds. The next year the first Morrill Act was passed by Congress, which donated public land to the states, revenue from the sale of which was to be used for the establishment of at least one college which would teach subjects related to agriculture and the mechanical arts. Governor John A. Andrew brought this act to the attention of William Barton Rogers, President of the Massachusetts Institute of Technology, which was then a paper corporation but nothing else. The Massachusetts governor had a great plan. He proposed that the Massachusetts portion of the money be used for a union of all the educational organizations in the Boston area, including the new Institute and a new agricultural college. It was the governor's idea that this great educational organization be centered around Harvard. What Harvard's reaction to this plan was, I do not know; perhaps it never got beyond the original suggestion to Rogers. In any case, President Rogers politely, but firmly, turned it down. As it turned out, it was this first Morrill Act that helped save M.I.T. from floundering completely in those early days, since the Institute, in the end, did receive part of the grant.

The suggestion that M.I.T. and Harvard be joined became a recurrent theme throughout the next 50

DETROIT PUBLIC LIBRARY

Walter R. Fleischer

Corinthian columns of Widener Library mark an important center of education at Harvard University . . .

years. Whenever there was a slump in the business cycle, there would be someone on the M.I.T. Finance Committee who would look wistfully up the Charles and start thinking what a fine match it would be for M.I.T. to become wedded to that wealthy institution. And, too, there were times when someone at Harvard would decide that the Lawrence Scientific School was not as strong as it might be. Then he would say: "Now I wonder if we couldn't persuade those Boston Tech people to come up here and become the School of Engineering and Science at Harvard."

The plot thickened in 1869 when Harvard elected Charles W. Eliot president. Where had they found him? At M.I.T., where he was professor of analytical chemistry and metallurgy. Nor is it without interest that when Eliot had been debating whether or not to join the Institute Faculty in 1865, a Harvard friend, Ephraim W. Gurney, had written to him, urging him to accept on the grounds that the direction of M.I.T. after Rogers should have passed off the stage might be as desirable as almost any educational post – and then Gurney added, "except that one out here in which I am determined to live to see you."

Soon after President Eliot's inauguration, he made his first serious effort to bring M.I.T. to Harvard. Perhaps he was homesick. William Barton Rogers, the founder of M.I.T., was still having more than the usual presidential worries over funds for his five-year-old college, and he knew President Eliot well and admired him. But of the proposal for a merger he said:

> I can see nothing but injury to the Institute from the projected change. The Institute has already taken the first place among the scientific schools of the United States, and, if untrammeled, will evidently continue to grow in reputation and numbers. Those who know our history know that this success is due to the opportunity we have had under the inspiration of modern ideas. No kind of co-operation can be admitted by the Institute which trenches in the least degree upon its independence. What is alone desirable is a friendly working of the two institutions in their respective spheres.

It is interesting in this connection to recall that President Eliot, before he went on the staff of Technology, had taught mathematics and chemistry in the Lawrence Scientific School at Harvard. While in that position he had come to know William Barton Rogers, who had been a member of the committee appointed by the Overseers of Harvard to visit the school while Eliot was teaching there. At that time Charles Eliot had drawn up what was, for then, a radical suggestion for the reorganization of the Harvard school. In James's biography, we learn that the plan as drafted by Eliot carried the following note: "I made this plan in the year 1861-62 when in charge of the laboratory of the Lawrence Scientific School. In 1864-65 the Institute of Technology was started very much after this plan." Certain it is that Eliot and Rogers had talked about the new importance of scientific and technological education, and agreed that those who studied in these fields should be broadly educated men as well as specialists. Certain it was, too, that Eliot had been influenced by the plan for a polytechnic school which Rogers had drawn as early as 1846.

After President Eliot suffered his first setback in carrying out his plans for a union of M.I.T. and Harvard, he made the Lawrence Scientific School a school of applied science, and succeeded in getting fundamental science transferred from its separate place in the scientific school into the college curriculum.

In 1893, when Francis Amasa Walker, the economist, was president of M.I.T., the question of whether M.I.T. should be made part of Harvard University arose again. This time the discussion was enlivened by a debate in the pages of the *Atlantic Monthly*. The dean of the Lawrence Scientific School was then Nathaniel Southgate Shaler. Dean Shaler threw down the challenge. In an article entitled "Relations of Academic and Technical Instruction," he made the case for having technological education carried out in connection with a university.

That was in August. In the September issue of the *Atlantic*, President Walker's article, "The Technical School and the University," made it clear that this was an M.I.T.-Harvard debate. President Walker began on this disarming note: "If any large part of Professor Shaler's position can be maintained, we are offenders against the cause of sound education. It is our duty at once to seek the sheltering arms of the nearest university; or, if there be none near enough to take charge of us, then we ought to disband, and send our students to those who can do better by them." Then, questioning whether a scientific school fared as well when connected with a university as when independent, he spoke of his own eight and one-half years of experience at the Sheffield School at Yale University: "So little had the school, in its early days, been considered by the corporation," he wrote, "that when the Battell Chapel was erected about 1873 no provision was made for giving the Sheffield undergraduates seats in it. . . . For myself, I believe that scientific and technical education always encounters a grave risk when put out to nurse with representatives of classical culture."

The next president of M.I.T. was a graduate of the Lawrence Scientific School and had taught there one year. James M. Crafts became president of M.I.T. in 1897. In his Report to the Corporation of 1898, he told of the negotiations which had taken place that year with Harvard, with a view to transferring to the Insti-

M.I.T. Photo

just as the Ionic columns under the Great Dome represent the focal point of learning at the Institute

tute the courses in civil, electrical, mechanical, and mining engineering, metallurgy, and architecture then being given at Harvard, as well as the use of the income from certain funds destined to the support of the courses. The Report continued:

It is impossible to give here the details of a long and friendly discussion in which the end held in view was the advancement of education and the diminution of undue rivalry; but in order to understand the eventual failure to carry out an agreement, it is necessary to say that the University Committee put forward the view that the charge of technical studies properly belongs with a university and that a union, however slight it might be, between the University and the Institute was desirable. The Institute Committee insisted upon the absolute independence of its government and believed that condition to be most favorable to the free development of studies in a school of applied science.

The most interesting part of the Report of the Institute Committee, which had carried out the negotiations, is the note on which it closed:

Although the result has disappointed our expectations, we still feel convinced that as friends and earnest promoters of instruction we can so direct the course of our respective institutions that they shall mutually help one another and avoid duplication of work. It is possible that such a result may be better attained by a friendly interpretation of our common purpose than by any attempt at a formal agreement. Your committee are encouraged in this hope by the very friendly acknowledgement of their reply to the Corporation of Harvard, which reads: "The President and Fellows regret that the alliance with the Massachusetts Institute of Technology proposed by them in a communication dated April 12, 1897, has failed. The President and Fellows cordially recognize the friendly spirit of the letter of the Committee of Conference of January 10, 1898, and will at any time meet the authorities of the Massachusetts Institute of Technology in consultation, for the purpose of avoiding unnecessary duplication of instruction."

By 1902 it had become clear to those connected with the Institute, or Boston Tech, as it was often called in those days, that the Back Bay location did not allow enough room for the expansion called for by the growing school. Debate about the future site and uncertainty over the future, marked the years from then until 1911, when the present Cambridge site was chosen.

Closely allied to the question of where to move was the suggestion, now raised with renewed insistency, for a merger with Harvard. A new reason had been added. In November, 1903, the will of Gordon McKay had been probated; and income from his endowment to Harvard was to be used for instruction in applied science: in particular, mechanical engineering. In November, the will was probated. The following January a new proposal for a merger of M.I.T. and Harvard was under discussion, and in May the first formal step was taken. A resolution passed by the Corporation of the Institute requested the Executive Committee "to ascertain whether any arrangement can be made with Harvard University for a combination of effort in technical education, such as will substantially preserve the organization, control, traditions, and the name of the Massachusetts Institute of Technology."

And who were the members of the Institute committee appointed to negotiate? The then President of the Institute, Henry S. Pritchett, and a member of the M.I.T. Corporation's Executive Committee — A. Lawrence Lowell.

A. Lawrence Lowell had been a member of the Corporation of the Institute since 1890, and for four years was a member of the Executive Committee. His grandfather, John A. Lowell, had been vice-president of the Institute from 1862 to 1870. His father, Augustus Lowell, had been a Corporation member. His brother, Percival, was the nonresident professor of astronomy in 1902 and later a member of the Corporation. As Lowell was to point out after he became president of Harvard, even his brother-in-law was a member of the M.I.T. Corporation. Nor does the Lowell connection end here. His nephew, Ralph Lowell, is at present a member of the M.I.T. Corporation and its Executive Committee.

At the time of these negotiations, in 1904, A. Lawrence Lowell was Eaton professor of the science of government at Harvard. The plan for a merger of the two institutions was one dear to his heart, and his biographer has said that his failure in this respect was one disappointment to which he was never reconciled. He once told a friend: "I have lain awake just two nights. One was about the Technology affair — and I have forgotten what the other was about."

In 1904-1905, President Pritchett's Annual Report gave the text of an agreement which had been drafted by the joint committee. By this time the Alumni of M.I.T. had been aroused and were becoming vocal in opposition to any merger. While the Institute would be semi-independent, retaining its name and its charter, the plan proposed that it move to a site on the Charles River opposite Harvard — probably the site of the present Harvard Business School. It would replace the Lawrence Scientific School and absorb its faculty, but Harvard would have control over its affairs.

As it turned out, the decision was made not by the Alumni or presidents, but by a decision of the courts which brought into question M.I.T.'s right to sell its land on Boylston Street in Boston. This decision made it necessary for President Pritchett to notify President

Eliot that it would be impossible to proceed with the plan for the proposed alliance. That this was a great disappointment to President Pritchett is indicated by the fact that when he wrote to Lowell to congratulate him on assuming the presidency of Harvard, he said: "What a pity we hadn't carried out the Harvard-Tech alliance."

Walter R. Fleischer

William Barton Rogers — John Harvard

Although neither was a native of New England, the founders of M.I.T. and Harvard University initiated educational reforms which were to make Cambridge an important center of learning in the United States.

In 1909, Richard C. Maclaurin was inaugurated as president of M.I.T., one month after A. Lawrence Lowell had assumed the presidency of Harvard. The merger question was still not dead. Maclaurin took the helm at the Institute at a time when great plans for a new campus were accompanied by a severe lack of funds. There were many who were ready to help the Institute with its plans for expansion, if it would be sensible and join with Harvard. However, the matter of a new campus for M.I.T. was soon settled by the mysterious Mr. Smith, whose gift of money made it possible to plan a new and more ample M.I.T. in Cambridge.

In a speech to a reunion banquet in 1909, President Maclaurin had had this to say about M.I.T.-Harvard relations:

> There will be no more talk of merger with Harvard, but I think we should be false to every precept of decency if we did not reciprocate most heartily the genuine expression of good will that President Lowell has so recently made, and I think we should be equally false to every precept of common sense if we failed to do our utmost to co-operate with Harvard wherever such co-operation is possible. I believe that in the domain of applied science there is much that we can do for our mutual help, but to make co-operation real and practical, we must be strong enough for independence.

And in President Lowell's report for 1911-1912, he said: "No plan of co-operation has been devised, but the difficulties ought not to be insuperable if approached with mutual good will and a sense that an educational institution does not exist solely for its own glory, but as a means to a larger end."

The merger question was settled once and for all, as President Maclaurin had said; but common sense still dictated that ways should be explored to prevent unnecessary duplication by the two neighboring schools. Once more an attempt was made to work out a plan whereby the schools of engineering would be joined. This time the negotiations were successful.

Early in January, 1914, came the announcement of a co-operative agreement between Harvard and M.I.T., whereby Harvard's courses in applied science would be carried on at the Institute. The Harvard faculty in engineering would work at M.I.T., but would retain their titles as members of the faculty at Harvard University, in addition to acquiring similar titles at the Institute. Of the 16 Harvard faculty members affected when the agreement took effect, six had already been associated with the Institute on its instructing staff, and four of them were Technology graduates.

Students who enrolled in the courses leading to degrees in mechanical, electrical, civil, sanitary, and mining engineering and metallurgy might elect to be candidates either for a Harvard University degree, for an Institute degree, or for both. They were to be entitled to the privileges of students in the professional schools at Harvard. Income from the McKay trust was to go toward the support of this school, as well as any other funds of the University or the Institute which were specifically designated for work in these fields.

President Maclaurin, in announcing the agreement, said: "Perhaps the most important outcome of the negotiations that have led up to this agreement, will be the proof to the world that great educational institutions do not shape their policies from selfish points of view. They think above all of the good of the community."

A poem by Edward S. Martin on the editorial page of the old *Life*, celebrated the occasion as follows:

> The lion with the lamb lies there
> And neither one inside:
> The Harvards skip a lot of care,
> The Techs conserve their pride.
> Instead of spending heaps of dough
> Each other's weal to check,
> The Techs at Tech to Harvard go
> The Harvards tech at Tech.

The joint school was short-lived. In November, 1917, the Supreme Judicial Court of the Commonwealth decided that the arrangement did not carry out the wishes of Gordon McKay and directed Harvard not to use the income from his trust in this way. That decision spelled the end of the joint school. But it was the beginning of a new era of co-operation between the two institutions, a co-operation which continues today.

To complete the story requires a postscript. Last year a distinguished panel, appointed by James B. Conant, President of Harvard, submitted to him a report on how Harvard could most effectively develop applied science under the now completed McKay bequest. Included in its recommendations are suggestions for concentrating Harvard's work in engineering in fields in which it can make an outstanding contribution, especially in educating men who can rise beyond their particular specialization, and bring a broad vi-

(*Concluded on page 62*)

Some Thoughts on Natural Flight

For All His Accomplishments in Aircraft Design, Man Is Yet No Match for Nature in Producing Flying Machines of Great Versatility

By JAMES L. G. FITZPATRICK

THE flight of birds and insects has endlessly challenged man and defied his genius for imitation. Their mode of flight, by gliding and the beating of wings (giving rise to aerodonetics and "orthopterics," respectively, if a coined word may be used), still provides interesting possibilities for the improvement of modern aircraft, and for the extension of air-transport services to fields as yet untouched. Among the many writers who have discussed these possibilities* is William B. Stout.[1] The consensus of these writers is that the versatility of nature's aircraft is unmatched. Their landing and take-off maneuverability are the envy of every designer. The flight of small birds over thousands of miles of open ocean is a marvel of airworthiness and economy of power. In such flights, birds frequently perform miracles of navigation as, for example, pinpointing a small ocean island. Their mastery of the air, the surface of the sea, and, in some cases, the waters beneath it, is the inspiration of countless inventors.

That the bird was man's teacher in the difficult art of flight is well attested by history. There is some doubt, however, about the conditions under which we students left nature's flying school. Did we graduate or are we still truants from the early grades? Does Professor Bird, in his feathery academic gown, still have a few tricks up his wing? Is Doctor Bug the last word on hovering flight? Alfred R. Weyl[2] and S. Paul Johnson,[3] '21, are among those who feel that these patient teachers have still much to impart to man by their examples.

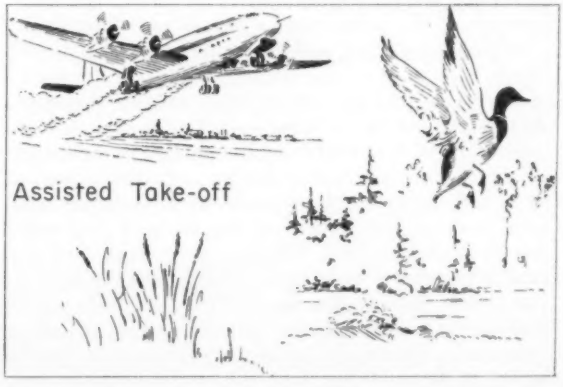
Our present understanding of natural flight is most limited; yet, over the years much careful and scholarly work has been done. A large number of inventors have sought to apply the scant store of knowledge to the complete duplication of the bird's flight performance. In addition, a number of successful design details have been advantageously copied from the bird. Among these may be mentioned the slotted wing, which reduces or eliminates the dangerous loss of control experienced at low speeds; the retractable landing gear; the fairing or smoothing of the wing to body joints to reduce resistance; the tapered wing form; the bleeding of small quantities of air through the wing surface to retain smoothness of air flow; the folding wings to improve ground handling and storage problems; and the catapult take-off. These and many other details may be credited to Professor Bird and his colleagues. In some cases, man has been clever enough to learn directly from his classes, as the illustrations indicate. In other cases, knowledge has been acquired in the dolorous school of hard knocks. Some of the knocks have been whoppers against terra firma!

The most complete and comprehensive texts on natural flight ever published, to which the late Antoine Magnan, a professor at the College de France, made extensive contributions, are published in French. An important recent addition, in Dutch, to the literature is E. J. Slijper's *De Vliegkunst in het Dierenrijk* (*Flight in the Animal Kingdom*).[4] The extent of the literature on the subject may be gathered from the fact that more than a thousand bibliographical references can be compiled.

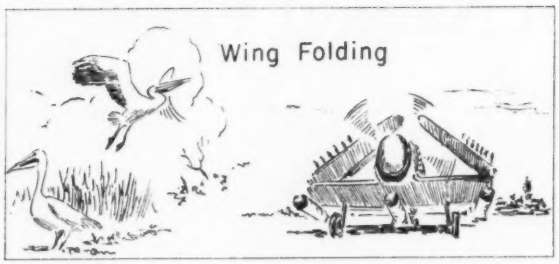
Studies of natural flight have suffered primarily from a lack of integration. The several sciences involved introduce numerous specialized jargons which restrict progress; by comparison, the Tower of Babel seems a small problem. Nevertheless, the study of natural flight is a fascinating subject and the summation of many respected opinions indicates that solid advantages will accrue from its pursuit. A brief review of some of the principal features of the problems of natural flight may indicate both the promise of progress which this field can offer and the obstacles which must still be overcome. In any case, a fresh point of view is always stimulating and often points the way to new progress.

For such a brief exploration of orthopterics, we may divide the subject into four parts, corresponding to the major scientific areas encountered: (1) biology; (2) aerodynamics; (3) engineering theory; and (4) engineering construction.

Drawings by M.I.T. Illustration Service



* Please see page 56 for numbered references.



Biology deals with the structural and functional adaptations which allow the creature to fly.

Aerodynamics is concerned with such questions as the details of air flow around the beating wings and the body of the flying creature, and the pressure and energy distribution in the air as affected by the passage of flapping or gliding bodies. When biology is combined with aerodynamics, we can begin to expect answers to such questions as: How much energy is needed in natural flight? How efficient is the biological flying machine?

Engineering theory develops hypotheses of design as we gain an understanding of the aerodynamic and biologic fields. It helps to determine whether there appear to be any limitations to the use of the orthopter type of flight mechanism on a large scale.

Engineering construction determines how we can apply the engineering arts to test the design hypotheses and how we can solve the problems of increased size. As applied to natural flight, this study opens up the possibility of a whole new field of engineering, based on knowledge of the welter of sinews, bone, chitin, and flesh.

Even a list of the outstanding detailed problems of each of the four divisions would require so much space as to tire the patience of the reader. Accordingly, one typical problem in each of these four fields will be selected for comment. The problems selected have a history which indicates that they have prodded man's mind generation after generation, like an uneasy cosmic conscience.

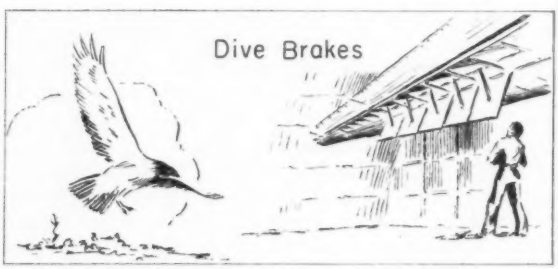
Biological Basis

In the biological area, we shall examine the problem of the power or energy demanded for the natural flight of birds. The interest lies in the comparison of natural, with man-made, aircraft. While weight and size differ greatly, we can at least select aircraft which have about the same speed range as the living flyers. Modern light aircraft and helicopters come within this range.

In looking into the energy requirements, we immediately encounter a typical difficulty. What little measurement is available on the natural flyers, whose efficiencies are not exactly known, is made on the basis of fuel input. On the other hand, aircraft performance is measured neither on the basis of fuel input nor of the real output. The horsepower rating of aircraft is an intermediate figure, much closer to the output power than to the input. There is a substantial body of opinion to indicate that, for natural as well as man-made flyers, the over-all efficiency is in the range of 20 to 30 per cent, which figure we accept, with reservations, for our comparisons. Lifting power will be expressed in British thermal units per hour, per pound lifted (B.T.U./hr./lb.) or in pounds lifted per horsepower (lbs./hp). In aeronautics, the latter standard is referred to as the power loading. The preferred term will depend upon the nature of the experiment under discussion.

The direct-energy measurement in the bird is very recent. Oliver Pearson[5] describes a study of the flight metabolism of the hummingbird and finds that, during hovering flight in a bell jar, these tiny creatures consume energy at a rate varying from 200 to 1,400 B.T.U./hr./lb., with an average of 726 B.T.U./hr./lb. In a hovering state of flight, a modern helicopter will use energy at the rate of approximately 750 B.T.U./hr./lb.

Energy consumption of insects in flight has also been measured by R. A. Davis and G. Fraenckel,[6]



L. E. Chadwick and Darcy Gilmour,[7] and August Krogh.[8] The insect is attached to a small rod by adhesive and buzzes violently when lifted clear of support. Measurements under such conditions show average rates of energy consumption to be close to that of the hummingbird. The low figure here is 180 B.T.U./hr./lb. Antoine Magnan[9] supported insects similarly, but measured the output energy present in the stream of air passing away from the insect. On the assumption of 25 per cent efficiency, Magnan's observations represent average input power of 170 B.T.U./hr./lb. All measurements are at least of the same general magnitude. It is perfectly obvious, however, that direct comparison among helicopters weighing two and one-half tons, hummingbirds of five grams, and insects at only a fraction of this, leaves much to be desired. Yet it is only at a most recent date that we have been able to proceed this far.

Otto Lilienthal,[10] the great and enduring pioneer of aviation, made experiments with a man-driven, beating-wing device suspended by a counterweight system. Lilienthal found that a lift equal to 70 pounds per horsepower could be obtained, which is equivalent to about 110 B.T.U./hr./lb. In my own experiments, with an artificial batlike machine, the rates in hovering ranged from 100 to 200 B.T.U./hr./lb.

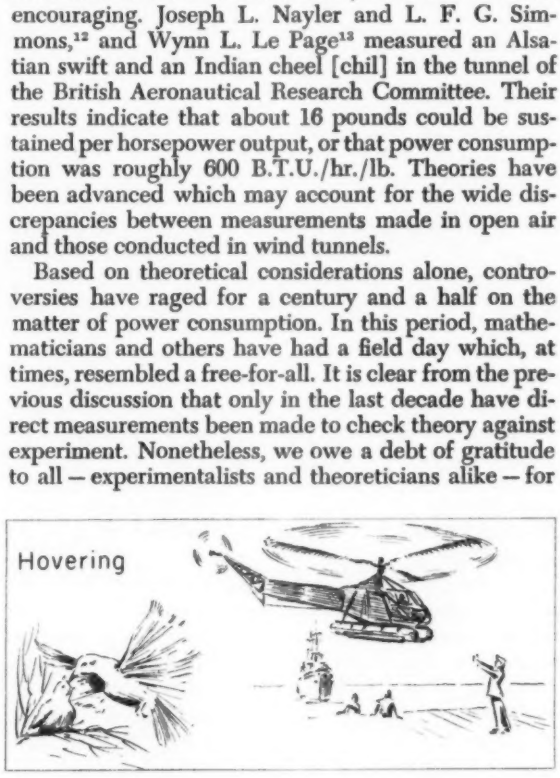
All of the preceding measurements refer, of course, to hovering flight or something which resembles it. Logically, we should now recite and compare the figures of direct measurement for normal flight; but, unfortunately, there are none.

The other extreme, from the high-energy rate of hovering, is the gliding condition. In this area, recent pioneer work by August Raspet of Mississippi State

College comes to our rescue.[11] The reports on his method tell of following a gliding buzzard with a fully instrumented sailplane. Bird and sailplane performance are telephoned to ground observers by radio. The experiment is conducted to allow subsequent accurate determinations of the speed and rate of fall of the bird. His flight behavior, wing positions, and so on, are a matter of record. Dr. Raspet finds that the power used by the gliding birds is equivalent to sustaining 268 pounds with one horsepower at a speed of 30 miles per hour (1,850 feet per pound per minute for a bird weighing 15 pounds). This is equal to about 38 B.T.U./hr./lb. A modern light airplane requires about six times as much power.

On the other hand, measurements of birds, or solid models of birds in wind tunnels, have not been too encouraging. Joseph L. Nayler and L. F. G. Simmons,[12] and Wynn L. Le Page[13] measured an Alsatian swift and an Indian cheel [chil] in the tunnel of the British Aeronautical Research Committee. Their results indicate that about 16 pounds could be sustained per horsepower output, or that power consumption was roughly 600 B.T.U./hr./lb. Theories have been advanced which may account for the wide discrepancies between measurements made in open air and those conducted in wind tunnels.

Based on theoretical considerations alone, controversies have raged for a century and a half on the matter of power consumption. In this period, mathematicians and others have had a field day which, at times, resembled a free-for-all. It is clear from the previous discussion that only in the last decade have direct measurements been made to check theory against experiment. Nonetheless, we owe a debt of gratitude to all – experimentalists and theoreticians alike – for



they have clearly traced out the questions which must be answered regarding this perplexing subject.

In 1829, J. Chabrier[14] suggested that, in some unknown manner, the bird recovers some of the energy which he expends in flight "by a recoil." Chabrier's figures would line up fairly well with Raspet's result, but a committee of academians, led by Claude L. M. H. Navier,[15] condemned Chabrier's result and estimated that power of approximately 10,000 B.T.U./hr./lb. is required in natural flight. James Bell Pettigrew, however, staunchly defends Chabrier's thesis in his great classic, *Animal Locomotion*.[16] The ordinary theory of flight assumes that energy is all irrevocably lost rather than regenerated. It is not easy to define accurately and in simple language the regenerative energy to which Chabrier refers. Nevertheless, if the center of an open umbrella is uncovered and the umbrella abruptly accelerated toward the handle, the subsequent air flow through the center section may be regarded as potential regenerative energy, since it moves in the direction of the aerodynamic reaction and thus offers the possibility of recapture. It is commonly accepted that one of the reasons for the V formation in flocks is that birds in the rear "recover energy" from the wake of those in front, or at least are not required to spend as much energy in flying as the leader at the point of the V.

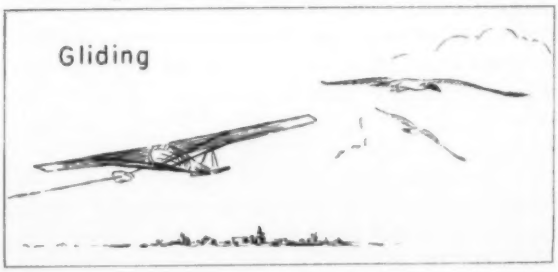
Lilienthal, already mentioned, was the early proponent of the importance of the oscillating flow of air on the wing. His calculations for a man-carrying, glider-launched machine would also be near approximate figures given by Raspet. Many others, such as Werner Schmeidler,[17] Isadore E. Garrick,[18] and Alexander Lippisch[19] give similar low-power requirements arrived at by calculation.

Louis Bréguet, versatile and venerable giant of French aviation, exposes another approach in *Le Vol à Voile Dynamique des Oiseaux*.[20] He expresses mathematically the well-supported opinion that the bird is able to extract energy from the roughness or turbulence of the atmosphere. Such soaring, aptly called dynamic soaring, is not to be confused with soaring near obstructions, soaring in thermal updrafts, or soaring in shearing layers of air having different velocities. In many cases, the energy extracted might be sufficient for steady flight, which need not be with the wind. Bréguet's estimate was that a great deal of power could be saved if a machine could be properly constructed to recover and use energy of turbulence.

It is most fortunate that the fledglings do not have to agree on the theory of flight before making their first trip from the nest! Man has certainly had his difficulties with the theory of flight, but even experimental results have caused many a headache. The wide disagreements among experimental results exhibit our present ignorance and hinder progress. New light is being thrown on the problem constantly, but the workers are few. Yet, here is a field in which the lack of success of some ill-considered past efforts has too often blinded research personnel to genuine and attractive possibilities.

Aerodynamics

We move now to consider a problem in aeronautics, a subject which has been developed by mathematicians and the wind-tunnel research workers, often working independently and strictly without adequate liaison among their respective groups. At best, there are severe limitations on the work to be accomplished. The mathematician finds large numbers of variables intractable. On the other hand, the wind tunnel is such an expensive instrument that it has not had wide



use in exploring systematically the domain of pure science. Commonly, use of wind tunnels is restricted to tests aimed to settle questions arising from contemporary or projected military or commercial designs. Such elementary matters as the resistance of air flow on bulbed bodies, similar to that of the bird, have apparently received little attention from either group; this, despite the known beneficial action of the bulbous prow on ships.

Specifically, the gnawing question in this field concerns the exact nature of the air flow about a beating wing. Most of us are familiar with the cross-sectional view of a wing with parallel streams of air parting smoothly over its blunt forward edge. The streamlines come close together over the deeply curved upper surfaces. Streamlines from the upper and lower surfaces unite at the sharp rear, or trailing edge, and leave at a slight downward inclination. Such behavior is readily understood and serves well enough to explain the elementary reactions of the steady flight of the ordinary airplane. The streamline concepts break down seriously, however, when applied to a wing having the type of oscillatory motion of natural flight.

In order to grasp the complexity of the problem posed by the beating wing, it may be well to review first a more complete picture of the air flow about the ordinary fixed aircraft wing. The action causing this wing to support or "lift" the airplane has been explained in many ways. Three of these explanations have a bearing on our problem.

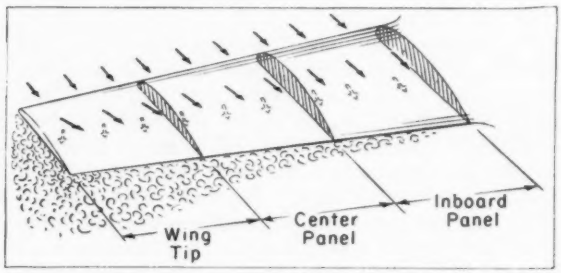
Bernoulli's theorem states that, in a flowing fluid, an increase in velocity will be accompanied by a decrease in pressure, other conditions being equal. The deep curvature of the upper surface causes an increase in velocity. Therefore, the upper surface experiences a drop in pressure; the reverse occurs on the lower surface. The upper surface is thereby pulled up and the lower surface pushed up.

Newton's law tells us that momentum is conserved in a collision. In accordance with Newton's law, when the air and the wing collide, air is thrust downward and the wing is thrust upward. The downward angle at which the air leaves the wing is called the downwash angle.

Frederick W. Lanchester[21] and Ludwig Prandtl developed the circulation theory.[22] Very much simplified, their theory states that a ring of air spins around the wing just as though the wing were the axle of a wheel. The difference is that the wheel is rotating in reverse. If you can visualize an automobile in reverse gear being towed rapidly through deep snow, you will have pictured the essential behavior. The reversed spinning of the wheels tends to throw the snow ahead of them and thus contributes support or lift.

It must not be imagined that there is any conflict between these three views. They are simultaneous and demonstrable facts in a complex process. Nor does the complexity, which resists efforts to decipher beating-wing behavior, end here. The wing is more fully equipped with curls than is milady leaving the beauty parlor; and no serious discussion of the aeronautics of natural flight should omit at least a reference to these phenomena. It is regrettable that those who fully understand the complexity of air flow on the fixed wing are sometimes prone to assume perfect simplicity when the wing beats.

We may roughly sketch out the behavior of the air about the fixed wing of the airplane as follows. We call the front edge of the wing the leading edge; the rear, the trailing edge. We will divide the wing roughly into three parts. The part nearest the body is called the inboard panel; the outermost part is called the wing tip, or tip panel; and the part between these, the center panel. The air over the center panel most nearly approximates the simple picture



we have drawn so far. However, the air on its upper surface tends to go toward the body, while that below tends to go toward the tip. As this top inbound stream meets the bottom outbound stream at the trailing edge, a series of corkscrew whirls or vortices result. These are left behind in the wake of the wing like so many twists of wood from a carpenter's plane. They form a sort of flat sheet. Keeping this picture in mind, now imagine the wing surface waving vertically about its leading edge as though the wing were a sheet on a clothesline in a stiff wind. The complicated system of vortices which results is the wake produced at the center panel – when the wing is in "steady" air flow.

The strength of the inward and outward flows of air increases the nearer the vortices are to the end of the tip panel. The crescendo is reached at the tip itself. Here a veritable niagara of air pours out from under the wing (the high-pressure area) and curls in over the top surface (the low-pressure area). This results in a giant whirl called the tip vortex. It has been demonstrated, both experimentally and mathematically, that this giant eventually absorbs all the other vortices. Less of the inbound and outbound spanwise flows occur at the inboard panel. Here, however, the air stream of the body of the aircraft is encountered. By this time it should be evident that it is inconvenient to take into consideration effects of vorticity when bent on explaining the broad basic principles of bird flight. It should be equally evident, however, that any explanation which neglects these facts is of dubious scientific or engineering value. Those who follow the course of exclusion are bound to disagree with those who do not.

Two relatively recent volumes which have contributed to the field on the first basis are *Bird Flight*[23] by Gordon Aymar and *The Flight of Birds*[24] by John Storer. In each, the phenomena which are susceptible of simple interpretation are interestingly covered, and both books have splendid photographs of bird flight.

(*Continued on page 46*)

United States Steel Corporation

These towering twins at the South Works of Carnegie-Illinois Steel Corporation produce 3,000 tons of iron daily.

The Basic Metal

Buttressing a Fundamental National Resource Is the Current Program for Expanding Steel Capacity

By PAUL COHEN

THE steel industry of this country, and, in fact, of the entire world, is currently in the midst of a productive, rather than a technological, crisis. The real problem of this basic industry is to provide the record-breaking amounts of steel required by its civilian and military consumers, and to obtain, likewise in record amounts, the necessary raw materials. In the first 12 months of the conflict in Korea, American steel plants poured out 101,934,000 tons of steel, representing more than 12,000,000 tons above production figures for the best year of World War II. This has been done amid the greatest expansion program the industry has ever undertaken, and at a time when many of the domestic sources of steelmaking materials are showing signs of exhaustion. In March of this year the S.S. *Bethore* docked at Sparrows Point, Md., with the first cargo of Venezuelan iron ore ever to reach this country. In June the Liberty ship, *Simeon G. Reed*, pulled into Baltimore to unload the first cargo of iron ore from Liberia.*

*The development of the mining and transport facilities to make such foreign ores available to American steel mills was described more fully in The Technology Review, 53:237 (March, 1951).

While these shipments may be described as an indication of this country's growing dependence on bulk imports of basic raw materials, to a degree, they are a secondary effect. After 10 years of the heaviest production it has seen, and after a decade of building that added almost 19,000,000 tons (between 1940 and 1950) to its rated capacity, the steel industry of this country is now engaged in a much greater expansion program. By the end of 1952, this industry's capacity — the official estimate of the tonnage which could be turned out if all equipment were worked to its designed maximum output with reasonable periods of down time for maintenance and repair — is expected to rise from slightly over 100,000,000 tons, the present figure, to about 118,000,000 tons (not counting some six million-odd tons of capacity in the western states).

This is not the future that was freely predicted when World War II ended. Said the *Minerals Yearbook* for 1944: "The annual production of steel ingots and castings for the five years following Japan's capitulation will probably average about 60,000,000 net tons." (It averaged nearer to 80,000,000 tons.) And the *Twentieth Century Fund*, in a survey of "America's Needs and Resources," declared that "Peacetime activity,

David W. Corson from A. Devaney, N.Y.

even under conditions of high-level income and employment, will undoubtedly leave the steel industry with surplus capacity and will considerably reduce the drain on iron ore reserves." For the five years ending with 1950, nominally years of peace, steel production averaged over 85 per cent of capacity. Since July, 1950, the rate has hovered about 100 per cent, and has been higher for weeks at a time. Total output for 1951 is expected to exceed 106,000,000 tons – the first 100,000,000-ton year in American history.

The erection of new capacity is permitting the steel industry to adjust its productive facilities to the new conditions of raw-material supply and consumer demand that the exhaustion of domestic mines, the passage of new laws, and changes in the American industrial scene have made advisable. Percentagewise, the greatest rise in capacity is being experienced in the East, and particularly in the Chesapeake-Delaware area, where some of the earliest furnaces in the country were built. The heavy concentration of population and industry in the East, more important than it was before the basing-point pricing system was outlawed by the courts, is a factor accounting for the growth of steel production facilities in the Middle Atlantic states, but accessibility to foreign ore is a more important one. Plans for about 8,000,000 tons of new capacity have been announced, although it appears that less than half this amount will materialize by the end of 1952. One of the plants, located on the Delaware River above Philadelphia, is well under way, and its projected capacity of 1,800,000 tons makes it not only one of the largest steel mills ever erected as a unit, but also comparable in output with the entire steel industry of Australia or India.

As far as the immediate future is concerned, the greatest increase in absolute terms is being made by the Pittsburgh-Youngstown district, which is still without serious challenge as the heaviest steel-producing area in the country. It is expected to gain, during 1951 and 1952, about 3,678,000 tons of new capacity. The East is gaining nearly as much (about 3,386,000 tons) for twice the percentage increase. It will soon be the East, rather than the Chicago region, that is in second place as a steel producer. The West, which increased its steelmaking capacity with exceptional speed during the war period, shows the smallest absolute increase, with 713,500 tons. There still seems to be no effective substitute for abundant raw materials transported mainly by water. With coal and iron deposits generally widely separated (the Kaiser plant at Fontana hauls most of its coal from Utah), the West is primarily dependent for its heavy transport on the railroads.

Similar difficulties are beginning to loom on the horizon for some of our older manufacturing regions. It is noteworthy that the Midwest, long apathetic about the St. Lawrence seaway, is shifting toward a strongly positive attitude. The realization is growing that, to maintain a flow of low-cost, high-grade iron ore into this great industrial region, access by ocean transport to the mines of the entire world must be assured.

The intense activity in producing steel, and in constructing new steelmaking capacity, that is currently characterizing the United States, is visible in many other countries, and for much the same reasons. Statistics of world production show that, in spite of the heavy damage done to the steel industries of three major producers – Germany, Russia, Japan – and the deliberate postwar throttling, until very recently, of German and Japanese output, world production today is not only substantially higher than it was before the war; it is higher even than at the peak of effort during World War II.

In 1939 the world produced 131,277,000 tons of steel. The United States was responsible for 35 per cent of it; Germany produced 19 per cent; Russia, 13 per cent; and Great Britain, 10 per cent. World output was 184,461,000 tons at the peak of war production, with the German and Japanese plants still virtually intact. In 1950, with German and Japanese outputs controlled by the occupying authorities, and with Russia completing a remarkable job of reconstruction, world production was 185,000,000 tons. As compared with the rankings of the various countries in 1939, some significant changes had occurred. The United States was first, with slightly over 50 per cent of the total (she had accounted for about 50 per cent of world output in 1929 also). Germany had dropped to fourth place and Russia, in second place with an output of 27,000,000 tons, was producing 60 per cent more than her 1939 production. In 1942, under the impact of Hitler's invasion of European Russia, Soviet output had declined to 9,000,000 tons. In 1950, Great Britain was in third place with about 9 per cent of the world's total steel production. In 1939, England had produced about 13,000,000 tons of steel. In 1950 she had produced about 16,300,000 tons. This year, output is expected to be less, although new capacity has been added, for lack of raw materials has so far

proved an intractable barrier to expanded production. Lately negotiations have been under way between Great Britain and the United States with the view of having this country supply England with 2,000,000 or 3,000,000 tons of steel next year.

It is difficult to avoid a comparison of these three countries – Great Britain, the United States, Russia – in relation to the present vigor and future outlook of their steel output, which in spite of every advance of metallurgy, remain the basis for all engineering and manufacturing industries. Great Britain, initiator of the industrial revolution and oldest of the industrial states, has not merely been stripped of top-grade iron ore; she no longer has adequate supplies of medium-grade ore. The domestic ores going into her furnaces are probably the poorest which are used on any large scale. Most of her pig iron comes from imported ore. Ships must bring in manganese, molybdenum, chrome, and many other vital steelmaking raw materials. If scrap iron is in short supply, or if the competition in world markets for material is fierce – and both conditions exist presently – there are no lush reserves to fall back on at home.

The United States is just beginning to see, on the horizon, the gaunt specters that have made themselves at home in England. Still far better off than Great Britain in relation to domestic reserves, still proud that, as far as a few alloying elements are concerned, she remains an exporter, the United States has prevented raw material shortages from pinching her booming steel production only by far-sighted planning, technically superb utilization of new, foreign mines, and tremendous bargaining power in world trade.

On the other hand, Russia's steel production, although only about one-quarter of America's, and representing, probably, a somewhat greater proportion of her over-all industrial effort than is poured into this country's steel output, is backed, according to *Iron Age*, by much larger domestic reserves, both relatively and absolutely, than is the case for this country. It is an inevitable consequence of her great land mass and her comparative industrial youth. Only in tungsten and molybdenum, apparently, is Russia seriously short of metals.

A large number of small nations have also had a hand in increasing world steel production, by striving with every resource to reduce or remove their dependence on imported steel. Chile, Brazil, and Australia are in this category. The new Huachopato steel plant near Concepción, Chile, with a capacity of 236,000 tons per year might be considered a minor element in a major industrial country, but it represents 10 times Chilean production before the plant opened. With materials, except for some of the coal, coming from local sources, it is expected not only to meet Chile's needs, but also to furnish an exportable surplus. The Volta Redonda steel mill in Brazil, currently producing about 300,000 tons per year, is in the process of an expansion program which may eventually double its capacity.

Most of the planned new capacity in the United States – actually 15.7 million tons as of January, 1951 – has been covered by the certificate of necessity which was granted by the government to companies whose plans for expansion are important to the government, and which might not otherwise be executed. Under this certificate the costs of a new plant can be amortized over a five-year period, instead of over the much longer period which is generally required for tax purposes.

A basic stimulus, however, is a world-wide hunger for steel. The steady increase in the world's population, at about 1 per cent a year, and an even faster increase (at least in the United States, Russia, and South America) in per capita demand, would be enough to keep steel industries expanding. Military requirements have also been a basic cause of heavy pressure on the steel industry. A much larger fraction of military, than of civilian, goods is "hard," and "hard" goods mean, for all practical purposes, products made of steel. What is more, a larger percentage of the raw material is apt to become scrap during the manufacturing process. A seven-ton tank turret, for example, may start as a 12-ton casting.

Heavy military demand for steel, we all hope, is a temporary phenomenon. A much sounder reason for the willingness of steel producers to expand output is that the civilian economy continues to show a persistent and growing appetite for steel – one that, surveys indicate may be of long duration. Nor is this trend restricted to the United States. The great technical and material resources of this country make it possible for demand to be met quickly by increased output, but an enormous latent market for steel exists in all countries. Every time a new cement mill is shipped to Iran, or a new railroad is erected in Venezuela, the world's need for steel is increased. Steel usage is like drug addiction; every new installation makes new uses for steel feasible, instead of bringing a step nearer the saturation of demand. A very elementary illustration is the automobile industry where the creation of a multimillion fleet of cars was made possible by, and simultaneously generated a need for, steel bridges to span rivers, roads of concrete reinforced with steel to carry the heavier traffic, pipe lines and refineries of steel to supply the fuel, acres of machinery to build and repair the cars, and so on ad infinitum.

As far as estimates can be made, there are currently in use in this country about one and a half billion tons of steel, or about 20,000 pounds for every man, woman, and child. One company alone, in the past 50 years, poured 940,000,000 tons of steel from its furnaces. With much of this accumulation the public never comes into contact. It is hidden behind masses of concrete, in the skeletons of buildings, in underground tunnels and conduits, and, of course, in the tremendous production plant of the country's industry. Because of a variety of protective or decorative covers, the public is likewise not consciously aware of many other articles made of steel which it handles daily, such as silverplate over forks and spoons; chromium over automobile bumpers or cocktail shakers; textiles over belt buckles; glass, porcelain, and paints over a wide range of household and industrial apparatus. A refrigerator is composed mostly of steel; on the average, there are about 170 pounds of it in each American white-robed kitchen goddess. A grand piano contains 220 pounds of iron and steel. There is more than a ton and a half of steel in the typical American automobile,

H. Armstrong Roberts

although a more representative figure, perhaps, is the 3,992 pounds of steel that are delivered to the automobile industry per vehicle produced. The average one-family house contains, all told, about four tons of the metal in various forms. This is very decidedly not the case in countries with lower standards of living. Even in Russia it is unlikely that houses are built without nails, but most assuredly when a Soviet couple step over the threshold of their new house, if they have been lucky enough to acquire one, they do not find a steel refrigerator, a steel washing machine, a stainless steel sink, a sheet steel gas range, and cabinets, steel springs under the nonexistent upholstery on the chairs, or a steel I-beam spanning the cellar. The relatively small amount of steel for civilian uses explains why Russian steel output goes much further militarily and in the manufacture of military equipment and durable goods than sheer tonnage, by American standards, would indicate.

Representing spectacular examples of steel used on a large scale are such structures as the Empire State Building, which contains 50,000 tons of steel; the recently completed 1,068-mile-long pipe line, extending from the Persian Gulf to the Mediterranean, which contains 325,000 tons of steel; and ships of the United States Navy, which it is safe to say, are well over 90 per cent steel. In light of the steel requirements per automobile, equally impressive is the fact that between 1946 and 1950 this country allocated about 20 per cent of the country's steel output in the manufacture of 25,000,000 new automobiles and trucks.

It is impossible to determine accurately the amount of steel equipment that is discarded or destroyed every year. Rough estimates of spoilage can be made from the amount of steel returned to the mills as scrap, and from the amount going into applications having a short life. For example, about 9 per cent of steel production goes into containers, primarily tin cans, which are not salvageable for all practical purposes.

As for obsolescent and broken equipment that is returned to the mills (the statistics are so prepared that such purchased scrap also includes some scrap created in the normal processes of manufacturing), it can be said that, roughly, it varies from a half to a third of the annual steel output. The supply of scrap is somewhat inelastic, and sharp increases in demand are apt to be met by increased use of pig iron. A study of the scrap cycle in Great Britain indicates that the scrap currently being returned to the steel mills in that country amounts to about 46 per cent of the steel being incorporated in finished form into the domestic economy. Many of the smaller European producers, prevented by various special circumstances (such as the lack of coal in Sweden and Norway) from using iron ore freely, use up to 90 per cent scrap in their furnaces.

Perhaps the most significant index of the increased dependence of the American economy on steel is to be found in the production per capita, since such figures are not confused, as are absolute production statistics, by the country's steady rise in population. From 1900, per capita production (virtually equivalent to consumption, since less than 10 per cent of this country's steel is normally exported) has grown from 300 pounds to 1,200 pounds as indicated in the following summation:

Per Capita Steel Production in United States

Year	*Lbs.*
1900	300
1910	633
1915	716
1929	1,038
1950	1,200

In World War I, this country turned out about 700 pounds of steel per capita per year; in World War II, about 1,300 pounds per capita.

These figures continue to represent about 95 per cent of the metal, structural or otherwise, used by the American people. In spite of the remarkable success of the metallurgists in recovering an impressive number of industrially useful metals from various ores that defied our ancestors, the basic fact remains that there is no substitute for steel. One can list the properties of engineering materials, from aluminum to zirconium without finding one material which can replace it as the connective tissue of our form of civilization. Although steel in all its forms has a rather remarkable range of behavior, its physical properties

(*Continued on page 42*)

Graduate Students in Physics

The Institute Plays a Disproportionately Large Part in Supplying the Country with Outstanding Physicists

By PHILIP M. MORSE

TRAINED scientists and engineers are the principal product of M.I.T. Particularly in view of the increasing technological phase of our present society, a not unimportant portion of this contribution is the Institute's output of graduate-trained physicists. During the 10 years before World War II, M.I.T. trained and granted degrees to more than 5 per cent of all who had acquired doctor's degrees in physics educated in this country during that period. Because of circumstances too numerous and well known to enumerate here, holders of master's and doctor's degrees in physics played an important role in World War II, and persons with such training have been since in very short supply. It is thus of some interest to analyze the Institute's record of admissions, degrees granted, and quality of output.

The 1949 edition of *American Men of Science*[1] is a very useful indicator of the quality of our output. It does not give a quantitative index of an individual's ability in his chosen field, but at least a listing in this volume indicates that the person is active in science and is rated by his colleagues as a contributing member of his profession. The graduate students who entered M.I.T. before the war have been out long enough now so that absence of listing in *American Men of Science* may be taken as an indication that they are no longer contributing members in the professional field for which they were trained, although they may be performing excellently in some other work. Using *American Men of Science* as a measure of effectiveness, this survey analyzes the record of those who have received M.I.T. graduate training in physics.

Data for this study were all obtained from records of the registration officer for the Department of Physics and are summarized in Table I. The records are fairly complete for those students who were in residence for at least one term, and the results quoted for this part of the analysis should not be in error by more than a few per cent. Data on students who applied for admission but did not register are less complete. Nevertheless, allowing for errors in judgment in evaluating the data, the over-all results are probably within 10 per cent of the correct values, and are certainly good enough to validate the conclusions drawn.

On the 148 students who were registered for one or more terms, as given in Table I, M.I.T. expended 761 student terms, 183 scholarship terms, 80 research assistantship-terms, and 248 teaching fellowship-terms to produce 26 physicists with S.M. degrees, 77 with doctor's degrees, and 77 with listings in *American Men of Science*.

TABLE I—*Record of Graduate Students in Physics, M.I.T., 1934–1942*

	No.	No. Incl. in AMS*
Applications received	679	(272)
Admitted to Graduate School	377	(198)
Registered one or more terms	148	(74)
Average attendance, 5.04 terms Average cumulative rating, 4.20		
Students who left, with no degree	48	(9)
Average attendance, 3.12 terms Average cumulative rating, 3.53 Scholarships, 1st term, to 10 Res. Asstships., 1st term, to 3 Teach. Fel'wshps., 1st term, to 6		
Students who obtained S.M. degrees	26	(11)
Average attendance, 4.00 terms Average cumulative rating, 4.30 Scholarships, 1st term, to 7 Res. Asstships., 1st term, to 3 Teach. Fel'wshps., 1st term, to 2 Three continued and acquired doctor's degrees		
Students who obtained Dr.'s degrees	77	(57)
Average attendance, 6.59 terms Average cumulative rating, 4.57 Scholarships, 1st term, to 32 Res. Asstshps., 1st term, to 3 Teach. Fel'wshps., 1st term, to 38		

*Figures in parentheses, in boldface type, represent inclusion in *American Men of Science*, 1949 edition.

During the eight years between January, 1934, and January, 1942, 679 applications[2] for admission to the Graduate School in the Department of Physics were received. Of these, 272, or 40 per cent, were from persons who are now listed in *American Men of Science*. It is clear, therefore, that applicants for graduate study in physics at the Institute included a fair percentage of potential scientists. Not all applicants were ad-

[1] Edited by Jaques Cattell (Lancaster, Pa.: The Science Press, 1949). $16.50.

[2] Applications are counted separately for each year; an application for a given year, from a person who applied the year before, but did not come, is counted as another application.

TABLE II—*Comparison between Recipients and Nonrecipients of Awards for Graduate Study in Physics at M.I.T., 1934–1942*

1st Term Awards	*No.*	*Fraction in AMS**	*Fraction Awarded Dr.'s Deg.*	*Fraction Awarded S.M.*	*Fraction Leaving No. Deg.*	*Cumulative Rating*
Teaching Fellowships	44	0.66	0.82	0.05	0.13	4.55
Research Assistantships	9	0.55	0.50	0.13	0.37	4.18
Scholarships	43	0.63	0.63	0.16	0.21	4.25
No Award	52	0.34	0.19	0.25	0.56	3.46
Total	148	0.50	0.51	0.17	0.32	4.20

* *American Men of Science*, 1949 edition

mitted, of course; some withdrew or did not complete their applications, some did not have a good undergraduate record, and others did not receive sufficiently high recommendations from their professors to appear to justify graduate study. Only 377 were admitted, of which 198, or 53 per cent, are listed in *American Men of Science*.

These over-all figures clearly indicate that those admitted to graduate study in physics achieved a higher degree of professional success than those who simply applied for admission, that is, 53 per cent as compared to 40 per cent. Nevertheless, we see that those admitted to the Graduate School did not include all the potential scientists who applied; 72 of the 303 not admitted are now listed in *American Men of Science*.

Failure to prophesy more precisely the future professional success of applicants which these figures indicate is not entirely chargeable to error in judgment of the Department committee, however, for many of those not admitted withdrew or did not complete their application. In addition, choice of likely candidates is dependent, to a large extent, on the letters of recommendation from former teachers who may be expected to know the candidate reasonably well. In the light of later achievements, detailed examination indicates that quite a few rank-order judgments included in letters of recommendation were faulty.

Not all candidates who were admitted actually attended M.I.T., of course. Many reasons account for the shrinkage. In some cases personal circumstances or professional interests changed; in others, the applicant obtained admission on a satisfactory basis at another educational institution. A large number of applicants stated that they would require financial aid in order to undertake graduate study. Often the necessary assistance was in excess of that we were able to provide, no matter how deserving the applicant. The Institute awarded some scholarships and fellowships, as did other schools, of course. Those who received no award went to the school of their choice, if they could afford to; otherwise, they gave up advanced study for remunerative employment.

The available awards were, of course, made to those applicants who were considered most likely to benefit from graduate study and most likely to make a success in their professional field. It is, therefore, important to see how well the teaching fellowship- and research assistantship-awards were made; this will be analyzed later in the article.

In the eight years between 1934 and 1942, there were 148 new graduate students actually registered in the Department of Physics, of which 74 are listed in *American Men of Science*. Of the enrolled graduate students, 48 never received advanced degrees; they failed in their class work, had financial difficulties, or completed their studies elsewhere. A good many of the 48 were not good graduate-student material, for their average cumulative rating was 3.53 (out of a possible 5.00), in contrast with 4.20 for the whole 148. But not all who failed to receive M.I.T. degrees were bad material; some got their degrees elsewhere, and nine are contributing scientists now, as judged by their inclusion in *American Men of Science*. Among the group completing requirements for degrees were 26 men who received master's degrees; their average cumulative scholastic rating was 4.30. Eleven of them are listed in *American Men of Science*. Three of these men continued their studies and acquired a doctor's degree at the Institute.

Of the 148 graduate students in Physics during these eight years, 77 obtained doctor's degrees, and 57 (the fairly high figure of 74 per cent) of them are listed in *American Men of Science*. Practically all of these men who had obtained doctor's degrees made significant contributions to the war effort; a number held responsible positions in the M.I.T. Radiation Laboratory, in research centers at Los Alamos, Oak Ridge, and other large war laboratories. Many of them are now world-famous scientists; others are in important executive positions in scientific organizations as head of departments or laboratory directors.

According to *Physics Today*,[3] less than 1,000 physicists were awarded doctor's degrees in the United States in the period of time studied, so that the 77 trained at M.I.T. was of the order of 10 per cent of the whole. (In 1949 this percentage was over 20; M.I.T.'s fractional contribution of graduate physicists has markedly increased since the war.) Of all the physicists obtaining doctor's degrees in the United States during the eight years under study, and who have also attained reputation sufficient for them to be listed in *American Men of Science*, it appears likely that the 57 from M.I.T. constitute *more than 10 per*

[3] 3:18 (December, 1950.)

cent of the total. This is by no means an unsatisfactory record and, as evidenced from the foregoing, it is even better since the war.

As indicated above, it is important to see whether the students awarded teaching fellowships or scholarships, on the basis of their undergraduate records, were of better quality than those who came without such financial encouragement. There were some cases in which the applicants did not apply for any aid or who came on funds supplied elsewhere. These cases dilute the figures but cannot negate the general conclusions given here.

The group of men (44 of the 148) who were awarded a teaching fellowship before entering Technology were supposedly the "pick of the lot." Twenty-nine of the 44, or 66 per cent, are listed in *American Men of Science.* This score is better than the average of all registrants (50 per cent) but not as good as the 74 per cent score for those who were finally awarded a doctor's degree as shown in Table II.

In regard to achievements both while at the Institute and afterward, the group selected by the Department to receive teaching fellowships the first term are definitely better than the average, although not as much better as one would wish; here then is room for improvement in initial selection. The group awarded tuition scholarships the first term are also better than average, although not as high as those awarded teaching fellowships. The scholastic performance of these two groups corresponds to the order of rating of the two awards. In general, men who have received research assistantships were no better than average. Before the war, however, research assistantships tended to be awarded to specialists, for their usefulness to the Institute in research projects, rather than for their capabilities as students.

Perhaps the most interesting figure is that for the men who were not given financial aid their first graduate term. They were not only decidedly poorer than the ones given awards but fewer of them became recognized physicists than the average applicant for admission. (Only 34 per cent are in *American Men of Science;* 40 per cent of those who applied are listed.) Apparently more of the better men not given awards at the Institute went elsewhere, presumably to some other institution which did give them an award. In order to have attracted more of the better men, the Institute would have had to award more fellowships. Those coming without awards were, on the average, those who had not secured awards elsewhere either.

It is also of interest to rearrange the data to indicate which schools supplied M.I.T. with its best graduate material in physics. Applications from graduates of 169 different colleges and universities were received during the eight-year period, and graduates from 75 attended at least one term here. The data according to source are not as complete and as accurate as the scholastic records of students considered above, and certainly the small number of applicants from some educational institutions makes statistical conclusions dangerous. Nevertheless a number of interesting results are apparent. In the first place, the numbers of applicants, as well as those who eventually were listed in *American Men of Science,* bear practically no relation to the size of the undergraduate school attended. Some smaller colleges have sent a disproportionate number of good graduate students to the Institute. It appears that the larger schools either retain their best students for graduate work, or possibly did not do as well as the smaller schools in providing undergraduate training in physics. Analysis of registration of those accomplishing their undergraduate work at the Institute tends to favor the former explanation.

During the eight years covered, 46 Institute graduates applied for admission to the Graduate School in Physics, of which only one was refused admission for reason of low grades. Of these applicants, 26, or 57 per cent, are listed in *American Men of Science.* This percentage is somewhat higher than the average (50 per cent) of all graduate students in physics. Registered in the Graduate School were 32 of the 46 applicants,

(*Continued on page 40*)

TABLE III—*Ratings of Institutions* which Supplied Graduate Students in Physics to M.I.T.*

School	*No. Applying*	*No. Admitted*	*No. Registered*	*No. S.M.*	*No. Dr.'s*	*Average Cumulative Rating*
Buffalo, University of	3 (3)†	3 (3)	2 (2)	—	1 (1)	3.3
California Inst. of Technology	7 (2)	6 (2)	3 (2)	—	2 (2)	4.3
Case Institute of Technology	7 (6)	7 (6)	5 (4)	—	5 (4)	4.5
Chicago, University of	6 (2)	6 (2)	3 (2)	1 (1)	—	3.8
Columbia University	5 (3)	4 (2)	4 (2)	1 (0)	2 (2)	4.3
Kansas, University of	4 (3)	3 (2)	2 (2)	1 (1)	1 (1)	4.1
Mass. Institute of Technology	*46 (26)*	*45 (26)*	*32 (21)*	*10 (5)*	*17 (14)*	*4.3*
New York, College of the City of	13 (6)	8 (5)	3 (2)	—	1 (1)	3.9
Oberlin College	14 (12)	13 (11)	6 (5)	—	5 (5)	4.8
Temple University	4 (3)	3 (2)	2 (2)	1 (1)	1 (1)	4.1

*Only those institutions are included for which the figure in parentheses in the third column is two or greater.
†Figures in parentheses, in boldface type, represent inclusion in *American Men of Science,* 1949 edition.

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Britons Give Special Lectures

Two distinguished British chemists, one a Nobel prize winner, delivered two special lectures at the Institute in mid-September. The visiting lecturers were Sir Robert Robinson, who spoke on "Syntheses in the Steroid Group" on September 19, and Alexander R. Todd, whose topic was "Some Recent Progress in Nucleotide Research" on September 21. Both lectures were given under the auspices of the Department of Chemistry. The speakers were introduced by Professor Arthur C. Cope, Head of the Chemistry Department.

Sir Robert Robinson, who since 1930 has been Wayneflete Professor of Chemistry at Oxford University, was knighted in 1939 in recognition of his substantial contributions to chemistry. The Nobel prize in chemistry was awarded to Sir Robert in 1947 for his investigations of biologically important plant products, especially alkaloids. A Fellow of the Royal Society of London, he also received in 1930 the Society's Davy Medal and its highest award, the Copley Medal, in 1942.

A past president of both the Chemical Society of London and of the Royal Society, Sir Robert has had a distinguished career as a professor of chemistry. In addition to his present post at Oxford, his teaching appointments have included the Universities of Sidney, Liverpool, St. Andrews, Manchester, and University College, London.

Alexander R. Todd, a former collaborator of Sir Robert's at Oxford, has since 1944 been professor of organic chemistry at the University of Cambridge. A graduate of the University of Glasgow in 1928, Dr. Todd studied extensively in Germany before World War II and has also been associated with the University of Edinburgh, the Lister Institute of Preventive Medicine, and the University of Manchester.

Elected a Fellow of the Royal Society of London in 1942, Dr. Todd received in 1949 the Society's Davy Medal, which is awarded annually for the most important European or Anglo-American discovery in chemistry. Professor Todd has specialized in structural and synthetic studies in organic and biochemistry with special reference to vitamins B_1 and E.

Higgins Professorship to Slater

JOHN C. SLATER, for 21 years Head of the Department of Physics at M.I.T., has been appointed Harry B. Higgins Professor of the Solid State, according to an announcement by Professor George R. Harrison, Dean of Science, in September. This professorship, recently established under a grant from the Pittsburgh Plate Glass Company, is designed to further theoretical and experimental work on the constitution of solids.

Scientists have always found it much easier to explain the behavior of matter in the gaseous and liquid states than in its solid condition, but in recent years important advances have been made in the elucidation of the structures of metals, other solids, and glass. Professor Slater has made outstanding contributions to these advances, and it is expected that his new appointment will contribute greatly to progress in this important field.

Only recently Professor Slater was appointed to the newly created post of Institute Professor, with freedom to conduct investigations using M.I.T. facilities without regard to departmental boundaries. Dr. Slater's appointment as Higgins Professor will enable him to engage in studies in which he has long been interested, and to which he has made substantial contributions.

Course X Administration

PROFESSOR EDWIN R. GILLILAND, '33, of the Department of Chemical Engineering and Associate Director of the Laboratory for Nuclear Science and Engineering at the Institute, has been appointed acting head of the Department, according to Thomas K. Sherwood, '24, Dean of Engineering.

Professor Gilliland will serve during the leave of absence of Professor Walter G. Whitman, '17, Head of the Chemical Engineering Department since 1934, who has been appointed chairman of the Research and Development Board of the Department of Defense in Washington. Professor Whitman succeeds William Webster, '23, and his appointment became effective July 15.

Dr. Gilliland, a member of the Institute's staff since 1934, served as deputy dean of engineering in 1945 and 1946. During World War II, Dr. Gilliland was a prominent figure in the nation's synthetic rubber program. From 1942 to 1943 he was assistant deputy rubber director in charge of research for the Rubber Administration, and for the following two years he was assistant rubber director. In 1945 he became deputy chairman of the Guided Missiles Committee of the Joint Chiefs of Staff and a member of the Technical Industrial Disarmament Committee. He had previously served as deputy chief of Division 11 of the National Defense Research Committee and chief of the Jet Propulsion Panel, Office of Field Service, for the Navy Department.

Dr. Gilliland has received wide recognition for his professional achievements. He was the first recipient of the $1,000 Leo Hendrik Baekeland Award of the North Jersey section of the American Chemical Society, and last year he received the Professional Progress Award of the American Institute of Chemical Engineers. In 1948, Northeastern University awarded him the honorary degree of doctor of engineering.

Franklin Institute Medals to Chipman and Collins

THE Franklin Institute has awarded the Francis J. Clamer Medal to Professor John Chipman, Head of the Department of Metallurgy, and the John Price Wetherill Medal to Professor Samuel C. Collins of the Department of Mechanical Engineering at M.I.T. Professors Chipman and Collins received the medals formally on October 17 at special Medal Day ceremonies in Franklin Institute's Franklin Hall.

The Clamer Medal, established in 1943, is given at least once in five years for meritorious achievement in the field of metallurgy. This year the award was given, by unanimous vote, to Dr. Chipman "in recognition of his contributions, as an individual and as a teacher, to the application of the theories of physical chemistry to steelmaking practice." His leadership in the field is recognized throughout the metallurgical world. Professor Chipman has been ranked as "the father of modern metallurgical thermodynamics" and as "certainly within the top group of three metallurgists in this country," according to Henry B. Allen, Executive Vice-president and Secretary of the Franklin Institute.

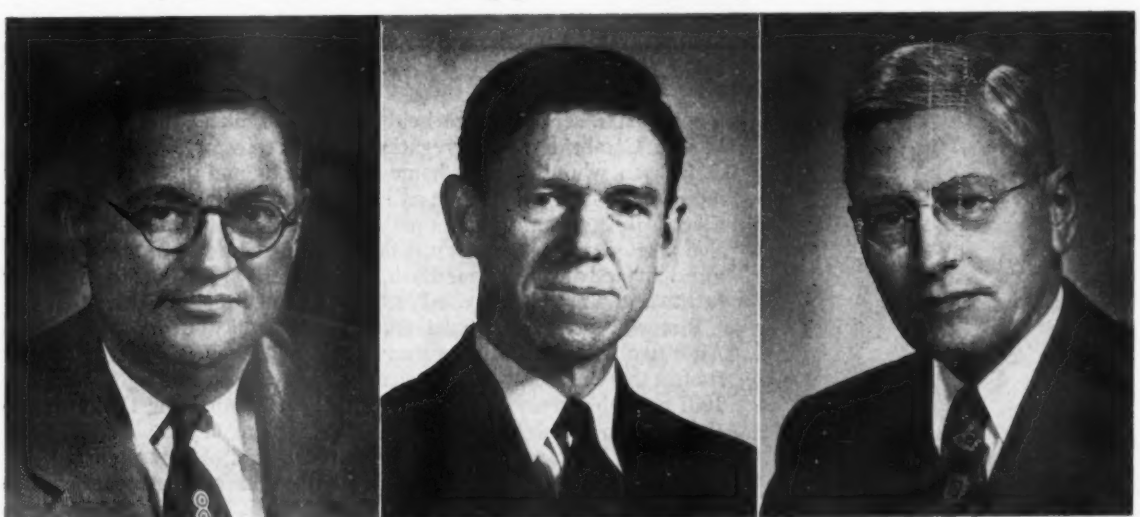
Turning his attention to steelmaking processes in 1929, Professor Chipman undertook to place the physical chemistry of steelmaking on a quantitative and sound theoretical base. More than any other single individual, he has been responsible for placing the mechanism of deoxidation in steelmaking on a quantitative basis, making it possible to determine the amount of deoxidizers, and the time and order of their addition to achieve the desired degree of deoxidation and the economical production of steel of a desired quality.

Professor Chipman came to M.I.T. in 1937 as professor of metallurgy and has been head of the Department since 1946. In 1942 he was director of the metallurgical project at M.I.T. which was part of the Manhattan Project, and in 1943-1944 he was engaged in work at the University of Chicago, as chief of the metallurgical section, where fundamental work related to the production of plutonium was carried out during World War II.

The John Price Wetherill Medal was awarded to Professor Collins "in consideration of the invention and subsequent development of the first liquefier of helium to operate without the aid of external refrigerants, an admirably designed, reliable machine which is produced in quantity and has materially increased the number of laboratories and persons engaged in work at ultra low temperatures." The Collins helium cryostat is considered the most important contribution to cryogenic technique since the original liquefaction of helium in 1908.

Professor Collins studied at the University of Tennessee and the University of North Carolina. While still working for his doctor's degree, he taught chemistry at Carson-Newman College and was an instructor in physics at the University of North Carolina. In 1930 he joined the staff of the Institute. In addition to his invention of the helium cryostat, of which 37 are now in use, Dr. Collins has done research on the thermodynamic properties of gases, production and maintenance of very low temperatures, and improvement of oxygen processes of low-pressure type.

In the same ceremonies at which Professors Chipman and Collins were honored, Howard O. McMahon, '41, a research associate in the M.I.T. Department of Physics and affiliated with Arthur D. Little, Inc., received the Edward Longstreth Medal for his major contributions to the success of the Collins cryostat. He prepared the original invention for production in quantity and was responsible for the excellent mechanical design of the machine. Dr. McMahon was a former student of Professor Collins', so that the award to Professor Collins may be considered a tribute to his teaching ability as well as to his research talents.



M.I.T. Photos

Three of the Institute's Faculty who have recently received recognition. (Left): *Professor Edwin R. Gilliland, '33, becomes acting head of the Department of Chemical Engineering, following the appointment of Professor Walter G. Whitman, '17, to a Washington defense post.* (Center): *Professor Samuel C. Collins received the John Price Wetherill Medal for his invention of the helium cryostat.* (Right): *Professor John Chipman was honored with the Clamer Medal for his work in the field of physical chemistry of steel manufacture.*

Dormitory Facilities Expanded

STUDENTS returning to the Institute for registration on September 17 found increased dormitory facilities. With the acquisition of Burton House, dedicated last June to the memory of Alfred E. Burton, the Institute's first Dean, M.I.T. now has housing facilities for more than 2,100 students.

Figures from the Registrar's Office, as of September 19, indicate a total of 4,777 students for the 1951-1952 school year – 3,133 of whom will pursue undergraduate work and 1,644 on the graduate level. The senior class will contain 923 members (this figure includes fifth-year students in the Courses in Architecture and Marine Engineering); junior class, 742; sophomore class, 724; freshman class, 744.

An innovation in campus living, inaugurated this fall, is the appointment of three Faculty residents who will live in the undergraduate houses. The Faculty residents and their families, who will occupy new suites in three of the undergraduate houses are: Professor John T. Rule, '21, Head of the Section of Graphics, and in charge of the Course in General Science and General Engineering, in Burton House; Frederick G. Fassett, Jr., Director of the Publications Office, in Baker House; and S. Curtis Powell, '37, Assistant Professor of Marine Engineering, in Munroe House.

Students this year will also see the completion, as part of the Institute's continuing Development Program, of two important research laboratories: the John Thompson Dorrance Laboratory, and the Sloan Metal Processing Laboratory.

The Dorrance Laboratory will house the Departments of Biology and Food Technology, and the specialized equipment necessary for research in these fields. The new laboratory building will provide facilities to meet an increasing demand for graduates technically trained in the cause of better health and food.

The Sloan Metal Processing Laboratory will enrich and extend the Institute's engineering program in a field of increasing technological importance.

M.I.T. Supports New FM Station

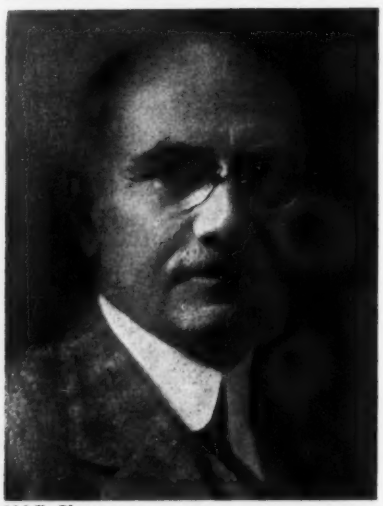
A NEW high-power noncommercial FM (frequency-modulated) station for educational broadcasting, bringing to the people of New England full-length live performances of the Boston Symphony Orchestra, as well as the cultural resources of Greater Boston colleges and universities, held its initial broadcast on October 6. The new station began its operation with the first Saturday evening performance of the Boston Symphony Orchestra's 71st season.

Ralph Lowell, trustee of the Lowell Institute School and member of the M.I.T. Corporation, announced that the Boston Symphony Orchestra has joined with the Lowell Institute Cooperative Broadcasting Council, organized in 1946 to promote adult education by radio and television in the New England area, to inaugurate the new station, which will have the call letters WGBH. The Lowell Institute Cooperative Broadcasting Council is composed of six colleges and universities of Greater Boston – Boston College, Boston University, Harvard University, M.I.T., Northeastern University, and Tufts College.

"This new radio station will be the only one of its kind in the United States in which a major symphony orchestra is collaborating with a group of colleges, universities, and other cultural institutions to offer a program of general education for all groups in the community," Mr. Lowell stated.

Consulting and supervising engineers in the construction and installation of the station are Professor William H. Radford, '32, of the M.I.T. Department of Electrical Engineering, and Emory L. Chaffee, '07, Professor of Applied Physics and Director of the Laboratories of Engineering Sciences and Applied Physics at Harvard. Station WGBH, with studios in Symphony Hall and transmitter on Great Blue Hill in Milton, will operate at 89.7 megacycles in the frequency-modulated band on channel 209, with effective radiated power of 20,000 watts.

(*Continued on page 36*)



M.I.T. Photo

Professor Dugald C. Jackson
Head of the Department of Electrical Engineering, 1907-1935

Dugald C. Jackson: 1865-1951

MEMORIAL services were held on October 21, at the First Church in Cambridge (Congregational) for Professor Emeritus Dugald C. Jackson, who died at his home in Cambridge on July 1, after having served with great distinction as head of the Institute's Department of Electrical Engineering for more than a quarter of a century. An impressive portion of the services was the lay appreciation of Professor Jackson delivered by Vannevar Bush, '16, formerly a vice-president of the Institute and member of the Electrical Engineering Department.

Professor Jackson graduated from Pennsylvania State College in 1885. After two years of graduate study at Cornell University, he joined the staff at the University of Wisconsin in 1891 before coming to M.I.T. in 1907 as professor and head of the Electrical Engineering Department—the position which he held until his retirement in 1935.

In 1919, Professor Jackson organized the firm of Jackson and Moreland, of which he was the senior partner until his retirement from active consulting work in 1930. During World War I, he served as lieutenant colonel of Engineers in France and as chief engineer of the Technical Board, and was made a chevalier of the Legion of Honor. In 1929 President Hoover appointed him as representative of the United States at the World Engineering Congress in Tokyo. He was also a member of the National Research Council from 1928 to 1936.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

For several years this space has been used to tell how Revere has collaborated with its customers, to mutual benefit. Now we want to talk about the way our customers can help us, again to mutual benefit. The subject is scrap. This is so important that a goodly number of Revere men, salesmen and others, have been assigned to urge customers to ship back to our mills the scrap generated from our mill products, such as sheet and strip, rod and bar, tube, plate, and so on. Probably few people realize it, but the copper and brass industry obtains about 30% of its metal requirements from scrap. In these days when copper is in such short supply, the importance of adequate supplies of scrap is greater than ever. We need scrap, our industry needs scrap, our country needs it promptly.

Scrap comes from many different sources, and in varying amounts. A company making screw-machine products may find that the finished parts weigh only about 50% as much as the original bar or rod. The turnings are valuable, and should be sold back to the mill. Firms who stamp parts out of strip have been materially helped in many cases by the Revere Technical Advisory Service, which delights in working out specifications as to dimensions in order to minimize the weight of trimmings; nevertheless, such manufacturing operations inevitably produce scrap. Revere needs it. Only by obtaining scrap can Revere, along with the other companies in the copper and brass business, do the utmost possible in filling orders. You see, scrap helps us help you.

In seeking copper and brass scrap we cannot appeal to the general public, nor, for that matter, to the small businesses, important though they are, which have only a few hundred pounds or so to dispose of at a time. Scrap in small amounts is taken by dealers, who perform a valuable service in collecting and sorting it, and making it available in large quantities to the mills. Revere, which ships large tonnages of mill products to important manufacturers, seeks from them in return the scrap that is generated, which runs into big figures of segregated or classified scrap, ready to be melted down and processed so that more tons of finished mill products can be provided.

So Revere, in your own interest, urges you to give some extra thought to the matter of scrap. The more you can help us in this respect, the more we can help you. When a Revere salesman calls and inquires about scrap, may we ask you to give him your cooperation? In fact, we would like to say that it would be in your own interest to give special thought at this time to all kinds of scrap. No matter what materials you buy, the chances are that some portions of them, whether trimmings or rejects, do not find their way into your finished products. Let's all see that everything that can be re-used or re-processed is turned back quickly into the appropriate channels and thus returned to our national sources of supply, for the protection of us all.

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THE INSTITUTE GAZETTE

(Continued from page 34)

Professor Struik

To Technology Alumni, as well as to the members of the Institute's loyal and patriotic Faculty and staff, the extracurricular activities with which Professor Dirk J. Struik, of the Department of Mathematics at M.I.T., has been charged are a matter of deep concern. In April, 1949, Professor Struik received wide publicity when a witness at the trial of 11 Communists in New York testified that he had lectured before Communist groups. Last July, Professor Struik was summoned to appear before a subcommittee of the Committee on Un-American Activities of the House of Representatives of Congress. Professor Struik, by advice of counsel, refused to answer most of the committee's questions on the grounds that his answers might tend to incriminate him. On September 12, Professor Struik was indicted by a Middlesex County Grand Jury on charges that he had advocated the overthrow of the governments of the United States and the Commonwealth of Massachusetts. As a result of this indictment, Professor Struik was immediately relieved of all Institute duties by the Executive Committee of the M.I.T. Corporation, pending the outcome of the indictment.

In a letter dated September 27, and sent to all Technology Alumni, President Killian reported in full on the facts of this case. Nevertheless, the issues raised are of such importance as to warrant a review, in these pages, of the Institute's policy on academic freedom.

The Institute's unequivocal opposition to Communism was made public on May 3, 1949, in a statement of policy, approved by the Executive Committee of the Corporation, and recorded in "President Killian's Statement on Academic Freedom and Communism," which appeared on page 432 of the May, 1949, issue of The Review. This policy, which is intended to deal justly with all concerned and looks to the courts for the proper and orderly handling of judicial matters, is still in effect, and has guided the Institute's action in subsequent developments.

The text of the public announcement of Professor Struik's suspension, dated September 12, 1951, is as follows:

Professor Dirk J. Struik, Professor of Mathematics at the Massachusetts Institute of Technology, has been relieved of all duties at the Institute pending disposition of his case in the courts.

In a statement announcing the suspension by the Executive Committee of the Institute's Corporation, James R. Killian, Jr., President of the Institute, said:

"On May 3rd, 1949, the Institute issued a statement expressing its unequivocal opposition to Communism as well as the Institute's firm adherence to the concepts of academic freedom.

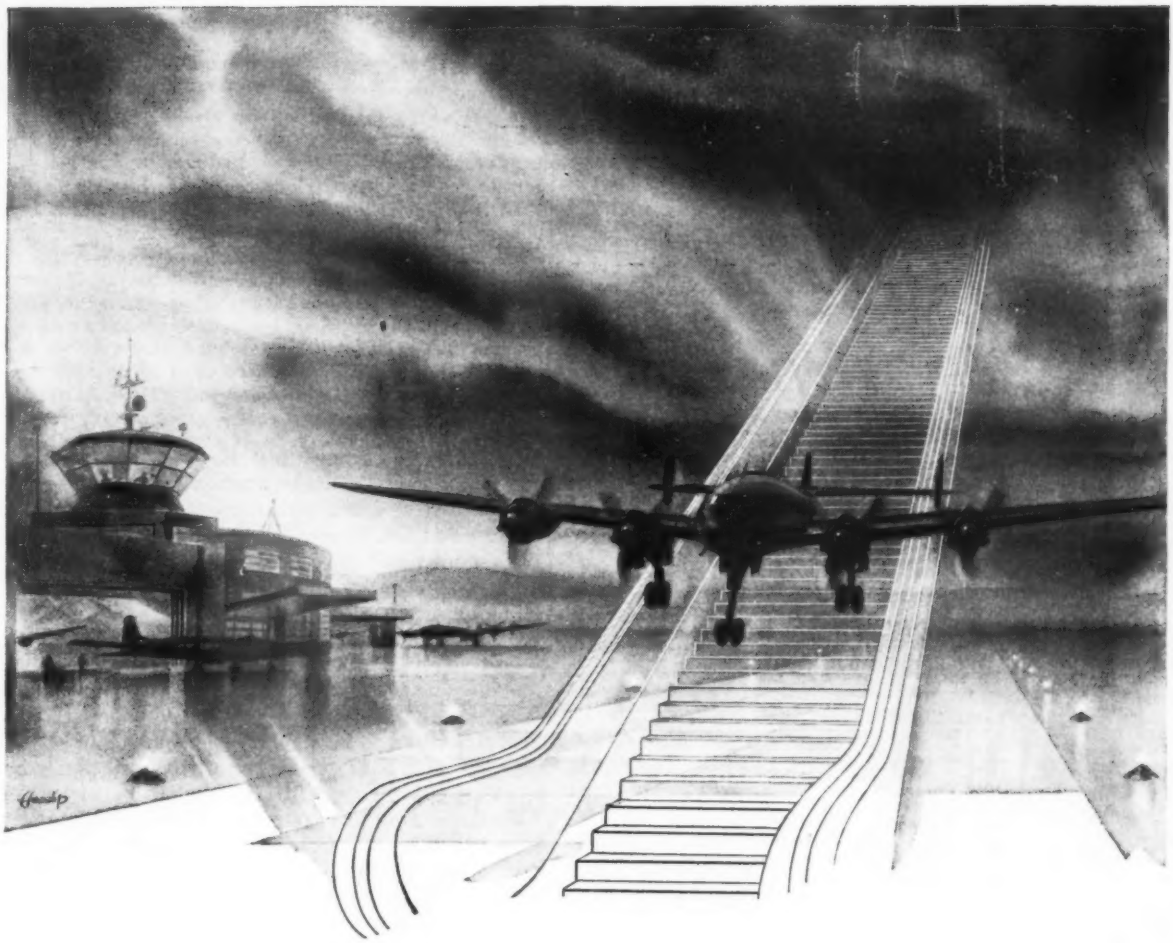
"In that statement the Institute expressed its belief that Professor Struik, who denied that he had committed any crime, should be considered innocent of any criminal action unless he were proved guilty. Furthermore, the Institute expressed its belief that if criminal charges were to be brought against Professor Struik they should be brought by the government and handled in the orderly procedure of the courts. An educational institution has no competence to carry on a trial to determine whether a law has been broken.

"In 1940, which was long before Professor Struik's political views and associations had been questioned, the Institute, acting in accordance with the traditional academic procedure followed in nearly all large universities, granted him an appointment to its faculty with tenure. Once granted, the well-established rights of tenure can be honorably withdrawn only on evidence of a

(Concluded on page 38)

Celebrating their 45th anniversary since graduating from "Boston Tech" on Boylston Street, members of the Class of 1906, and their wives, gathered for a well-attended reunion at Snow Inn, Harwichport, Mass., on June 13, 1951. Those present when this class photograph was made are: (left to right, front row) Michael J. Gibbons, Herbert J. Ball, Mrs. Norton, Harry L. Lewenberg, Dr. Lemuel D. Smith, James W. Kidder, Allyn C. Taylor, Edwin B. Bartlett, William G. Abbott, Burton W. Kendall, Chester A. Hoefer; (second row, kneeling) Edward B. Rowe, Sherley P.Newton, Floid M. Fuller; (third row, standing) Otto B. Blackwell, Andrew B. Sherman, Mrs. Sherman, John F. Norton, Mrs. Rowe, Mrs. Lewenberg, Mrs. Hoefer, E. Sherman Chase, Mrs. Coes, Harold V. Coes, Mrs. Guernsey, Mrs. Chase, Mrs. Taylor, Andrew Kerr, Mrs. Kidder, George R. Guernsey, Mrs. Fuller, Mrs. Kendall, Mrs. Coey, Stewart C. Coey, Malcolm G. Wight.

Sidney B. Moody



Escalator from the sky

Remember a few years back when overcast and low ceilings closed airports . . . canceled out airline service? When folks were saying, "they'll never lick weather . . . never operate with the regularity the traveling public demands"?

Today, however, the demand is for accommodations . . . because the demand for regularity is being fulfilled. And one of the major factors in this conquest of weather has been ILS (instrument landing system), which alone has eliminated over 55% of former bad weather cancellations.

ILS is virtually a *radio-beam escalator*, with related instrumentation in the cockpit. A small instrument with cross pointers enables the pilot to guide the plane, both horizontally and vertically, down this gradually descending beam to a prompt landing on the designated airstrip. Thus ILS, together with long-range, high altitude flying over radio signal highways, is virtually sweeping bad weather aside.

This cross-pointer indicator, vital to ILS, is also a WESTON development . . . the result of leaders in aviation seeking the answer to this critical problem here at instrument headquarters. Just as leaders in all other industries turn to WESTON for the instrument solution to problems involving measurement, recording, or control. WESTON Electrical Instrument Corporation, 635 Frelinghuysen Avenue, Newark 5, New Jersey . . . manufacturers of Weston and TAG-liabue instruments.

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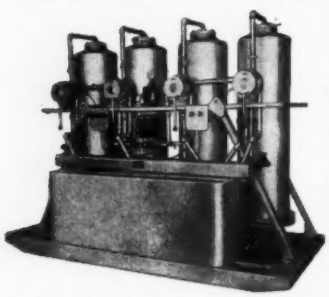
- Rectifying Liquor
- Coating Solutions
- Aircraft Research
- Washing Ampules
- Laboratories



If you use water in your operations, it will pay you to find out how a Barnstead Demineralizer can help you. In countless processes better results are obtained, when pure water — free from harmful minerals is used. In fact, hundreds of manufacturers have already found that they save money, have fewer rejects and get a better product with Barnstead Demineralized Water. The cost is extremely low — as little as 5c per 1000 gallons. Operation is very simple. And with a Barnstead Demineralizer, you get the benefit of more than 75 years of specialized experience in water purification. Write for Catalog #123.

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THE INSTITUTE GAZETTE

(*Continued from page 36*)

disregard of the obligations of loyalty, responsibility, and integrity which are fundamental requirements in any academic position. Until now the Institute has had no basis to justify a reconsideration of Dr. Struik's status.

"In 1949 the Institute stated: 'Should a member of our staff be indicted for advocating the violent overthrow of the American Government or other criminal acts, or if the evidence of such actions were incontrovertible, immediate action would be taken which would protect the Institute and at the same time preserve his rights. If this staff member should be convicted of this charge, he would be discharged.'

"The suspension of Professor Struik as of this date is in line with our announced policy."

At its first regular meeting following this announcement, the Faculty of the Institute passed a unanimous resolution in approval of the policies underlying the Institute's action.

The courts will now determine whether Professor Struik is innocent or guilty of the charges brought in the indictments.

Professor Struik has never been given access to "secret" material or projects or any classified information affecting the national security. He has never participated in classified projects. No evidence has ever been submitted to indicate that his classroom activities were other than would properly be expected from a professor of mathematics.

Throughout this episode, which has caused M.I.T. deep concern, the Institute has brought to bear the best judgment it could obtain on all aspects of the problem. The Institute's Administration has sought to act on principle and not on expediency, and it has acted on the firm conviction that the policy outlined in the statement of May 3, 1949, was the honorable and proper one for an American institution dedicated wholly to American ideals and traditions and to the advancement of truth. In accordance with these ideals and traditions, the Administration will not knowingly employ a member of the Communist party.

Freshman Week End

TRADITIONAL Freshman week-end exercises at the Institute began on Thursday, September 13, with an attendance of 625 freshmen, representing about four-fifths of the 744 enrolled in this year's entering class. For the first time in the history of the freshman orientation program, participating students were housed together in the east campus dormitories.

At their first class luncheon the freshmen were greeted by E. Francis Bowditch, Dean of Students, who, in succeeding the late Everett M. Baker, is beginning his first academic year as dean of students, and by Robert M. Briber, '52, President of the senior class and of the Institute Committee. The luncheon inaugurated a busy four-day week end designed to acquaint the new men with the normal procedures of campus and classroom life at the Institute.

What GENERAL ELECTRIC People Are Saying

C. E. EGELER

R. F. VANDEN BOOM

Lamp Division

ILLUMINATION MAINTENANCE: Illuminating engineers, and to a lesser extent, consumers of light in industry, have long realized the gradual but serious cumulative loss in illumination resulting from dirt on lamps and reflectors. Most manufacturers simply are not aware that where there is no regular cleaning, the light loss may be as much as 50 per cent. This is no doubt due in part to the paucity of actual test data regarding the rate of depreciation in lighting levels which occurs under various service conditions.

The operating cost of a lighting system always involves energy, lamp and lamp replacement (labor) costs. In a typical medium-sized plant using two-lamp 40-watt fluorescent industrial units, with energy at 1½¢ per kw-hr, 85¢ net lamp cost for a 40-watt fluorescent lamp, a 50¢ cost of random lamp replacement and 4500 burning hours per year, the over-all annual operating cost excluding investment amortization is $8.10 per 2-lamp luminaire. Two cleanings per year will provide a 42 per cent increase in illumination, or $3.40 worth of light. For a given average illumination the required investment will likewise be substantially reduced. Even though this investment factor be ignored, any cleaning cost up to $1.70 per fixture pays a real dividend. With systematic maintenance, a two-lamp 40-watt fluorescent unit usually can be cleaned for about 35 cents.

Defense mobilization imposes on industry an imperative responsibility for the most effective use of production facilities and manpower. Good lighting becomes more vital than ever, particularly when it is remembered that in the increment of needed workers there will be a greater proportion of older people who need the higher illumination levels to compensate for impairment of vision and age.

National Technical Conference of the Illuminating Engineering Society
August 27–30, 1951

C. G. SUITS

Research Laboratory

METALLURGICAL RESEARCH: The gas turbine, most modern powerplant for aircraft, locomotives, and other machinery, could be made appreciably more powerful with the same fuel consumption by relatively small improvements in certain metals.

Present gas turbines operate at a turbine inlet temperature of 1400 to 1500 degrees Fahrenheit. When this temperature can be increased a mere 100 degrees (by developing metals able to withstand such increase in temperature), the fuel required for a given output may be decreased five to seven per cent, and, equally important, the net power output from a plant of given size may be increased 15 to 20 per cent.

The future of many products of industry rests squarely upon future improvements in the metallic materials of which they are made. That is the simple reason for the extensive activity here directed toward the understanding, improving, developing, designing, engineering and manufacturing of alloys.

Although the type of fundamental and exploratory research performed in the G-E Research Laboratory is more commonly found in a university environment, the experience of 50 years has shown the great value of this approach in an industrial laboratory. Such research has added materially to the standard of living of the American public.

Metallurgy Conference
Schenectady, New York
August 22, 1951

★

L. L. GERMAN

Knolls Atomic Power Laboratory

RADIATION MONITORING: To illustrate the radiological aspects of civil defense according to air and surface types of atomic explosion, I would like to present a system of radiation monitoring which has been worked out by a group in Schenectady for use principally within the first hour after the explosion. Undoubtedly, many effective systems of this nature have been developed throughout the country.

For both types of explosion, it will be necessary to determine the location of the center of the explosion. This task can be accomplished by the use of simple units called "lampshades"—so named because of the shape. The metal lampshade functions on the effect of shadows created by the generated heat and light at the time of the explosion. Mounted at various locations around the target area, so that there will be at least four units within five to ten thousand feet from a burst any place within the target area, a shadow will be cast on the inside painted surface of the lampshade at the time of explosion. Wardens will be assigned to read these units, and should two or more wardens report direction and altitude angle, the headquarters unit can then determine ground zero and the height of the explosion. Since the position of the bomb explosion can be fairly well defined by a minimum of these units, considerable information is supplied quickly by available and simple facilities.

The radiation measurements required for both types of explosions are determined by simple ionization chambers strategically placed throughout the city so as to surround the potential target area. The ideal system would consist of a placement of these chambers on a grid system separated by approximately 1500 feet.

Civil Defense Communications Conference
Syracuse, New York
September 13, 1951

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GRADUATE STUDENTS IN PHYSICS

(*Continued from page 31*)

of whom 21, or 66 per cent, achieved the distinction of listing in *American Men of Science*. Their record is decidedly above the average. Presumably this keeping of the better students happens in all large institutions having good graduate schools.

This result again sheds light on the relation between fellowships awarded and the attendance of good students. The Institute awarded first-year fellowships, assistantships, or scholarships to a higher percentage of M.I.T. men who registered as graduate students than to applicants from other schools (77 per cent compared to 65 per cent, as given in Table I). Presumably, other large schools did the same; apparently if M.I.T. did not compete favorably with his alma mater in regard to fellowship awards, the better student from a large university stayed where he was. Graduates from the smaller schools had a different problem; if they were to acquire advanced training they had to go elsewhere. From these places the Institute could obtain the better student without having to overcome inertia as well as award competition.

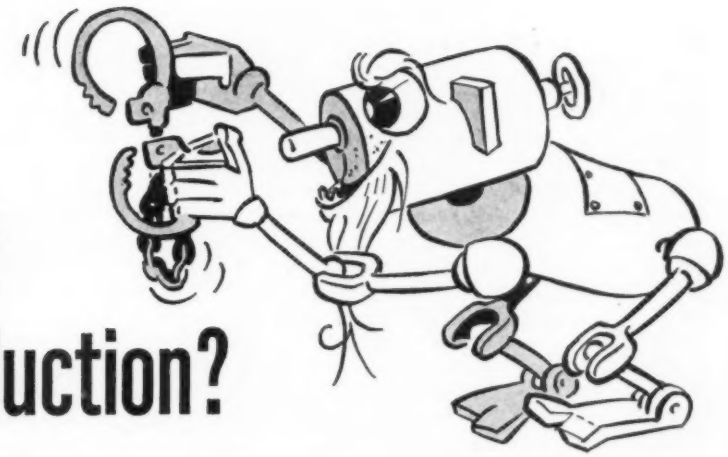
The result of this inbreeding in the larger institutions is that non-Institute graduate students tend to come from a wide variety of small colleges, none of which sends very many men. In fact, only from nine other schools did the Institute receive a sufficient number of good students so that at least two are now listed in *American Men of Science*. The record of these schools is shown in Table III.

Two small institutions — Oberlin College and Case Institute of Technology — stand out above the rest and, on the whole, rank above our larger sources, except M.I.T. (within the accuracy warranted by the small numbers). Two Canadian universities have also sent outstanding men; Dalhousie and McGill, but in these cases the *American Men of Science* criterion does not apply.

The complete rating of all schools from which any application came during the eight years uncovers a number of puzzling items. For example, a number of good students from some schools (Union College, Carnegie Institute of Technology, Cornell University, and so on) have applied for admission but very few actually registered. This is in contrast to the situation for Case or Oberlin, where the majority of applicants did come to M.I.T. Again, why did the Institute do so much better in choosing the good men from the University of Michigan than from Cornell, for example. (There is some indication that the system of student advisers and recommenders differed widely at these two schools, for in one case the letters of recommendation were mostly from people who did not know the student very well.) Detailed consideration of a number of specific cases indicates that personal acquaintanceship between faculty members in the M.I.T. Department of Physics and at the school from which the applicant came very materially improved the chance of success of this complicated process of "student-picking-school" and "school-picking-student." Wider range of personal contacts on the part of the Institute staff would quite likely have improved our score.

(*Concluded on page 46*)

Why Let Old Equipment Handcuff Production?



IT PAYS TO KEEP PACE WITH MACHINERY PROGRESS

PRODUCTION STANDARDS have changed in 20 years with changes in machines and methods. But how many 20 year old machines are there in *your* shop . . . cutting production . . . lowering efficiency?

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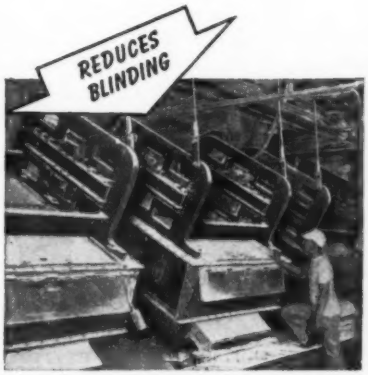
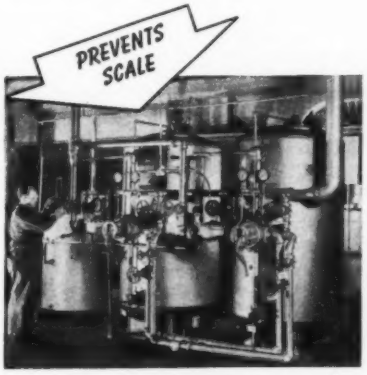


Utah Electric Screens

Handle fine granular materials from 10 to 48 mesh (dry) or 65 mesh (wet). Finger tip control of amplitude of vibration. *Vari-Pulse* non-blinding device cleans screen mesh automatically.

Electrifugal Pumps

Solid cast iron with no joints from motor end housing to pump casing assures permanent alignment. Installation is quick and easy. Pump comes ready to run. No extra parts. Requires small space.



Water Conditioning

Reduces costs by preventing scale in your coolant cycle; cut maintenance costs. This zeolite water conditioner is being used to guard against scale, foaming, carryover, corrosion, and expensive blowdown.

Magic-Grip Sheaves

Mounts and demounts faster than any other sheave you can buy. Once mounted they run true . . . cannot slip or jam. You save time and eliminate the danger of damaged bearings and shafts from forcing and hammering.

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ALLIS-CHALMERS

THE BASIC METAL

(*Continued from page 28*)

alone do not account for its extensive use. Some types are among the strongest substances known (except for laboratory curiosities) both absolutely and on a strength to weight ratio; others have unique magnetic and electrical properties; a few have corrosion resistance of a high order, as metals go. Steels still handle most high-temperature applications. Yet while nearly every individual technical property of steel can be duplicated, or exceeded, by some other material, about the only practical substitute for steel that is worth even minor consideration is wood. The dominating criteria are not, in the end, technical, but are based on the twin factors of availability and cost. There are a few ores — aluminum, magnesium, and titanium — which are found in comparable or greater quantities in the earth's crust than is iron ore. None of them are as cheaply or as easily reduced to metal as is iron ore. It might have been, in the absence of iron, that greater efforts would have been made to exploit other metals, particularly aluminum and magnesium, although it is a little hard to imagine how methods of extraction for these metals would have been developed in the absence of a technology created by centuries of effort; and it seems dubious that such a technology would have grown with the same rapidity had there been no iron and steel to support it.

Next to steel, in volume and availability, wood is the most important engineering material. In a year of heavy production, approximately 35 billion board feet of lumber are produced in this country. Making the assumption that, on the average, 1,000 board feet weigh 2,700 pounds, the United States has available about 47,000,000 tons of lumber, in a year of heavy demand. This does not include wood pulp, much of which is made from trees that could not furnish structural timber. Rather significantly, this country's peak year, as far as lumber production goes, occurred in 1909, when over 44 billion board feet were cut. In that year, per capita production of wood was about 1,200 pounds, while per capita steel production was about half of that. Today the situation is almost exactly reversed, with lumber production at about 600 pounds per person. But the clock cannot be turned backward. As the forests of this nation have shrunk, population has increased, and per capita usage continues to eat into reserves.† We could not restore the per capita production of 1909, except possibly under the direst short-term emergency conditions. And even if we could, we would not easily stomach the many unavoidable engineering limitations that would ensue. Properly handled, wood is a very respectable engineering material indeed, with a highly satisfactory strength to weight ratio. But wood cannot fill the gigantic shoes of steel. One cannot easily conceive of a satisfactory wooden landing gear for the *B-36* inter-continental

(*Concluded on page 44*)

† In this country the ratio of drain to growth (for combined saw timber and pole timber) has decreased from 4.34 in the 1909-1918 decade to 1.02 in 1944, according to the United States Forest Service.

B.I.W.

TWO FLEXIBLE HIGH-TEMPERATURE COAXIAL CABLES FOR USE ON AIRCRAFT AND ELECTRONIC EQUIPMENT

These cables are high-temperature modifications of standard Type RG cables which will withstand continual change in temperatures without damage to the insulation.

The insulation consists of the use of teflon tape applied in a unique manner and sealed from moisture and air. The tradename for this product is "Teflex" for which patent has been received. The characteristics of the insulation are such that the cable will withstand temperatures as low as —80°F and up to 500°F for long periods of time with very little deterioration in dielectric breakdown, power factor, attenuation, change in capacity or corona forming voltage.

These cables have been adopted and approved by ASESA as standard RG cables. The electrical and physical characteristics of these cables are as follows:

RG—115/U RG—8/U; 9/U; 9A/U COX—2FS—13—GV —65°C to + 250°C	ASESA NUMBER EQUIVALENT TO ASESA NUMBER BIW TYPE NUMBER TEMPERATURE RANGE	RG—124/U RG—59/U COX—3FS—026—GV —65°C to + 200°C
#13 stranded silver-plated copper	CONDUCTOR	#22 copperweld
"Teflex"; diameter .250" plus or minus .005"	INSULATION	"Teflex"; diameter .135" plus or minus .005"
Double silver-plated copper diameter .300"	SHIELD	Single tinned copper diameter .180"
Double "Teflex" layer	MOISTURE SEAL	Single "Teflex" layer
Double fibreglass braid impregnated with silicone varnish	OUTER COVER	Single heavy fibreglass braid impregnated with silicone varnish
.370" plus or minus .010"	OUTSIDE DIAMETER	.240" plus or minus .008"
Blue tracer	BIW MARKER	Orange tracer
.14 lbs. per foot	NET WEIGHT	.05 lbs. per ft.
50 plus or minus 2 ohms	IMPEDANCE	73 plus or minus 3 ohms
29 plus 2 mmf/ft.	CAPACITANCE	20 plus 1 mmf/ft.
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THE BASIC METAL

(Concluded from page 42)

bomber, of a timber Empire State Building, or of a wooden covered bridge over the Golden Gate.

The overwhelming fact about steel is that, of all metals used in this country (and, it is safe to say, in every other industrialized state) ferrous alloys constitute better than 90 per cent. In 1950, when this country's steel production reached 96,900,000 tons, copper output was 1,054,000 tons, that of zinc was 910,000 tons, lead was still less, and aluminum output was 718,000 tons. Were net imports and metal recovered from scrap to be included, the figures for the nonferrous materials would be raised slightly, but the basic picture would remain unchanged. The needs of the armament program are currently shifting the relative ranks of these nonferrous metals, mainly by causing heavy increases in the output of aluminum and magnesium. The goal is 1,500,000 tons of aluminum, but whether that metal is first or fourth in rank among the nonferrous metals, the position of steel remains dominant.

An index, if not an explanation, of steel's primary importance is its price. Throughout most of the Twentieth Century, the nonferrous metals have cost from five to 20 times as much as pig iron, and the ratios between the costs of the metals in fabricated form do not weaken the price advantage of steel. Iron ore is easy and cheap to mine, or at least it has been to date, and although ores may become leaner, or may be brought from more distant lands, no sharp increase relative to other mining operations seems imminent. Steel is cheap to produce from ore or scrap, not only in terms of needed materials and power, but also in terms of long-established large-scale plants. Its sheer volume of output, the skill and engineering knowledge that have been built about its use, the tremendous chain of suppliers and fabricators, all help to maintain its position. Without exception, other metals have either poor supply situations (rich, large-scale copper deposits are nearly as extinct as the dodo), technically difficult extraction problems (as in the case of titanium), or they consume tremendous amounts of electricity during the refining process (as in the case of aluminum and magnesium).

Almost since it was first manufactured, steel has been the symbol of military strength and industrial might. The United States can take comfort in the fact that, with the decisions and force that characterize its major actions, it is buttressing a fundamental national resource – the capacity to make steel.

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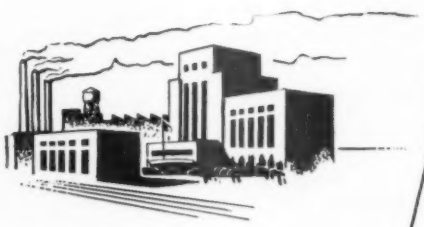

GRADUATE STUDENTS IN PHYSICS

(Concluded from page 40)

Among the major conclusions which can be drawn from this study are that: (1) the Institute plays a disproportionately large part in supplying the country with outstanding physicists; (2) the number of good physicists obtaining advanced degrees from M.I.T. has a positive correlation to the amount of financial support we make available to the entering graduate student; and (3) a disproportionately large fraction of our good graduate students come from small schools. The greatest improvement the Institute could make in our choice of students, to whom teaching fellowships or scholarships should be awarded, would be to devise a better method of selecting the good men who come from the small colleges. In particular, a method for improving the accuracy of information given in letters of recommendation, from the applicant's teachers, would probably produce a considerable improvement in the quality of our graduate physicists.

Another conclusion which is supported by this study is that the performance of those who applied late for admission (March–September, inclusive) was definitely lower than those applying early (October–February, inclusive). The average performance of graduate students in Physics at the Institute would have been improved if admission had been closed approximately around the first of April.

NATURAL FLIGHT

(Continued from page 24)

We have already referred to Chabrier's doctrine of regeneration and to those who kept alive this seed. Before 1925, two notable advances were made toward a further understanding of the doctrine. Albert Betz,[25] working mathematically, and Richard Katzmayr,[26] using a wind tunnel, showed that an oscillating stream of air meeting a wing may reduce wing resistance or even make it self-propelling. Lilienthal[10] had noted this phenomenon by flying a certain type of kite in natural wind; and the children of India have a similar kite which stands vertically overhead, and when struck by a sudden gust, it even moves into the wind, ahead of its owner.

Regrettably, neither the experimental studies nor the mathematical approaches have given us much information on the energy relations involved. René Moineau,[27] Henri Girard,[28] M. Denis,[29] and M. Tricot,[30] among others in France, have studied related phenomena. They have shown that vibrating wings or fins in water have what is called auto-propulsive or hyperlifting properties. The latter term refers to an abnormal capacity to sustain weight when in this condition.

The in-and-out or spanwise flow of air, especially in the wing tip section, has not escaped attention.

(Continued on page 48)

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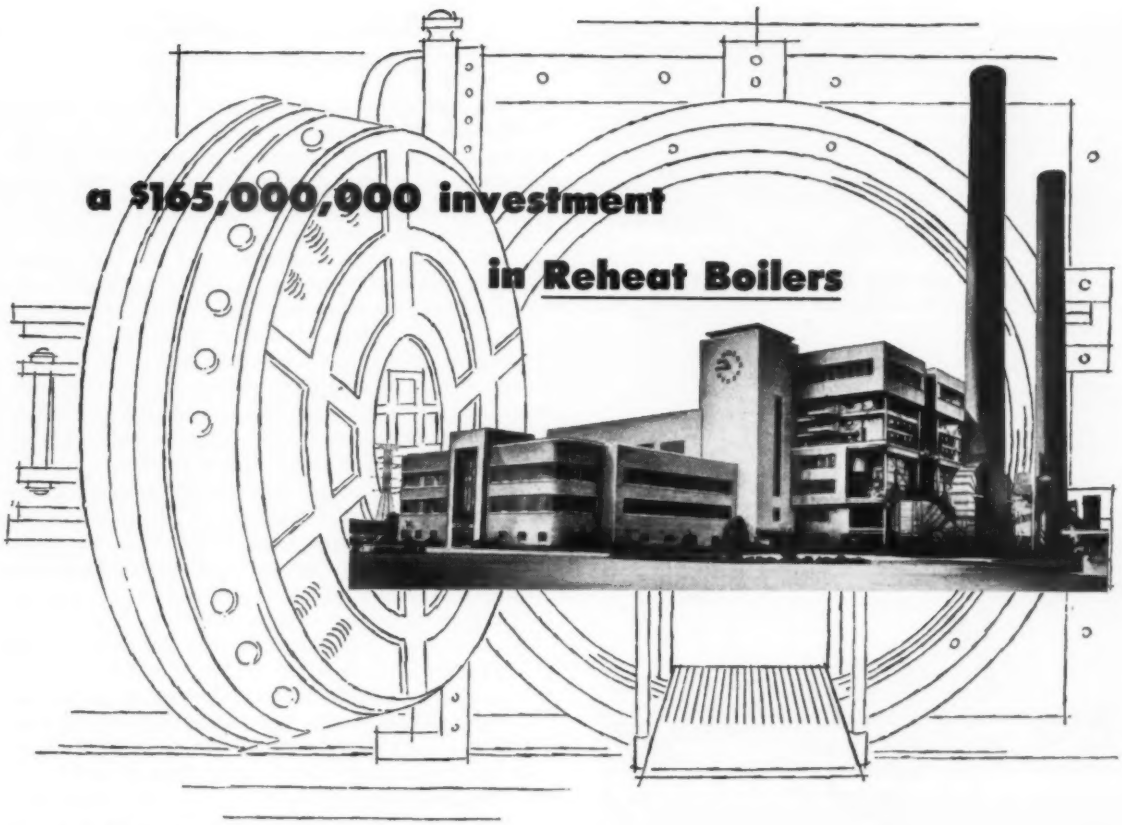

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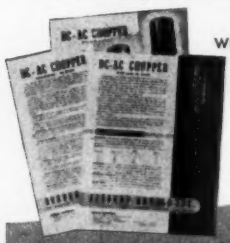

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NATURAL FLIGHT

(Continued from page 46)

Modern high-speed aircraft have accelerated some of these tests. Friederich Budig,[31] a former chief engineer of the Rumpler Aircraft Corporation, spent the latter part of a busy engineering lifetime exploring what he called the "oblique attack effect." This effect deals with the performance of a wing which is scoured in an angular direction by the air stream. Budig also claimed a self-propelling action under such circumstances, and his tests were verified on a large scale by the French Air Ministry. He constructed beating-wing machines on full scale which were flown without a pilot while tethered to the ground. In addition, he experimented with water fins, and a small fin-propelled boat which he built was found by the Ministry of Marine to yield a high efficiency.

The work of Bréguet, previously cited, exploits both the Katzmayr effect and the flattened M forward view of the bird's wings. His analysis would indicate that the flattened M construction is as important to flapping flight as it is to dynamic soaring. It unquestionably alters the nature of the air flow.

In Australia, Lawrence Hargrave[32] was among those who noted another vortex of air in birdlike wings. Eugen Sänger,[33] in the Vienna wind tunnel, showed that this vortex begins under the wing near the body and progresses outward toward the tip. Various and conflicting claims have been made for its effect on the wing performance, but again more work needs to be done to reconcile past observations.

There can be no doubt that numerous phenomena connected with the bird's wing can contribute to the diminution of power required for flight. The Designer who put the wing together seems to have known His business. Undoubtedly progress in flying could be accelerated were we in better position to understand fully the complicated behavior taking place. The large number of permutations and combinations of these phenomena which are possible do provide obstacles in any theoretical or experimental studies to be undertaken. But the gain seems worth the effort.

Suppose that we know of five specific phenomena, each of which separately yields an increase of a few per cent in efficiency. What will the optimum combination yield? We know enough of the situation to realize that it is not likely to be the arithmetical total. Poor combinations may act to seriously diminish the efficiency.

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In aerodynamics, moreover, the axiom "small cause, small effect" is not to be relied upon. We are still dealing with a science which is far from fully developed. To be sure, definite advances have been made and many pieces of the puzzle are at hand. But assembly of the fragments into a developed science is only beginning.

Some of the more definite gains, staked out in a century of work, pertain to the paths of wing motion in the bird and in the insect. We are positive, for example, that during the normal level flight of the bird, the wing partly folds and unfolds. R. H. J. Brown, of Cambridge University, is now completing a series of three-view motion picture photographs showing the wingbeat cycle of the pigeon – from hovering, up to 30 miles per hour. G. Guidi, in Italy, has also photographed the hovering condition. The unanimity of opinion on flight procedure among the pigeons should serve the cause of international harmony. Antoine Magnan, in France,[9] F. S. J. Hollick, in England,[84] and C. H. Curran, in this country,[85] are among those who have recently studied the wingbeat of the insect. Albro Gaul,[86] another American, is piecing together an attempted solution of the high-frequency muscle action of the insect.

Aside from direct observation, the last 20 years have yielded much on the behavior of the insect-type wing. Erich Von Holst,[87] in Germany, has studied beating and rocking insect-scale wings in a precision miniature wind tunnel. His conclusion, that such scale wings can be made to yield lift in almost any direc-

(Continued on page 50)

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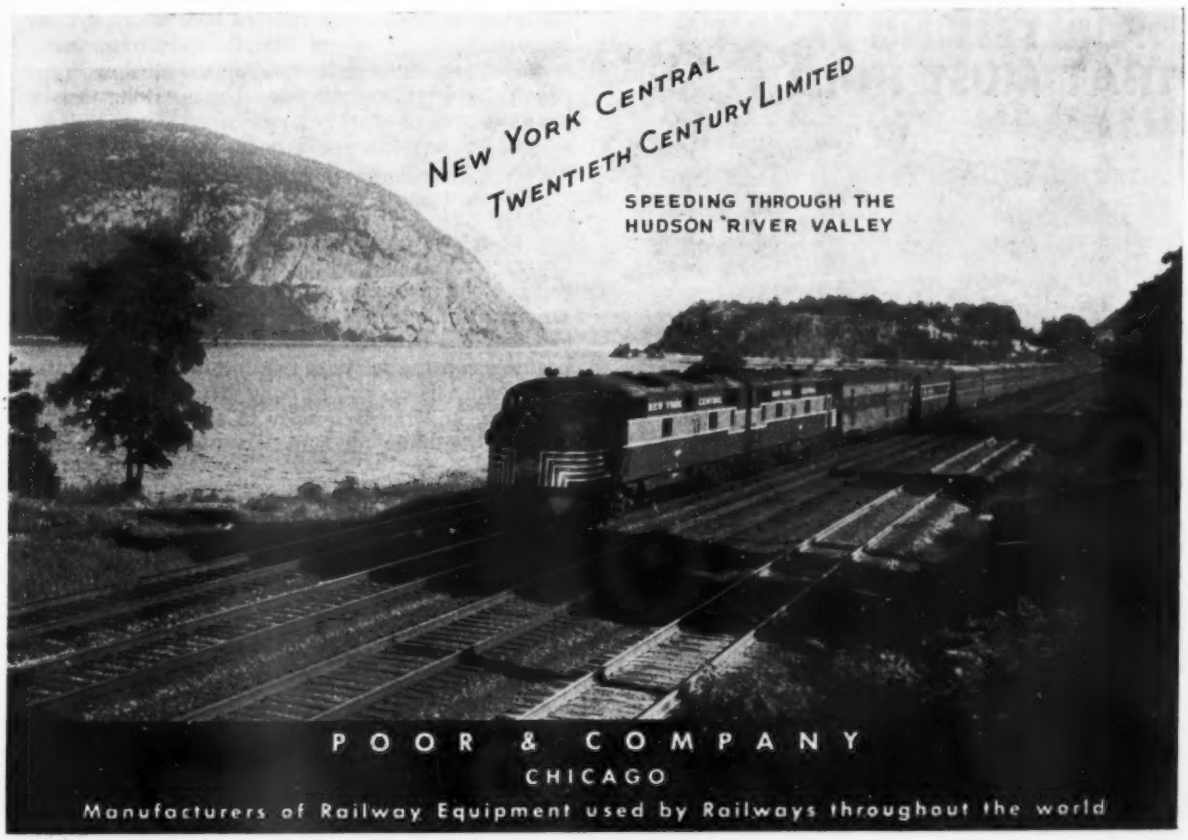

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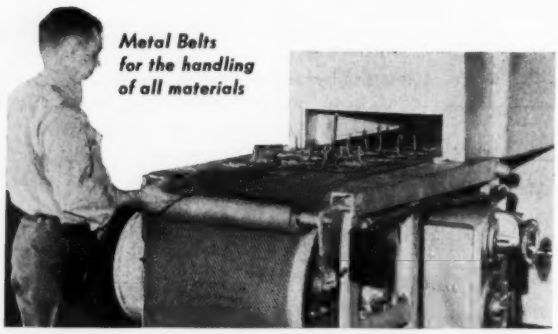

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NATURAL FLIGHT

(Continued from page 49)

tion and at high efficiency, is worth noting. On a somewhat larger scale, Alexander Jordanoglu, in Greece,[38] and, on a full-sized scale, William B. Stout, in Phoenix, Ariz.,[1] continue their important experiments. It is clear that nature's flying school is neither devoid of promise nor of students.

In other directions, work such as that of Arthur Fage and F. C. Johannsen[39] in England on the frequency of the whole vertical waving motion of the vortices shed by the trailing edge suggests that there may be a close relation between this and the normal wingbeat frequency. The approaches of Hans Wagner,[40] Hans Goerg Küssner,[41] and their successors to the annoying problem of flutter in wings has widened our horizons. In connection with the problem of regeneration, it is worth noting that this flutter represents a feedback of energy. In the Dayton, Ohio, area C. O. Horst and Adam Stolzenberger[42] are carrying out research: the one, seeking in the bird-wing design improved performance for conventional aircraft; the other, devising and flying flapping-wing models whose beat, in tune with the aeroelastic frequency of the model, is induced by an unbalanced weight.

The mature point of view must prevail. We cannot now make judgment since the case again is not complete. Tests are limited in application, the mathematical approach unsolved, or *mirabiledictu* funds are lacking to complete the work. However, it should be clear to those familiar with mathematics that the many variables "assumed out as insignificant" in smooth-flow aerodynamics return here with a vengeance. New variables are literally hidden in every feather. Progress in understanding the air flow is apparent, but again we must say that the fuller insight lies ahead.

Engineering Theory

In the third problem area delineated, we ought to find that the basic precepts of natural flight read like an open book. Regrettably, we do not all read the book of nature alike. At last report, the vegetarians and the beefeaters were still at odds. A problem that has here bothered science from its earliest beginnings is the relations existing in a given natural flyer among its weight, its wing area, its wingspread, its speed, and the frequency of the wingbeat. The pioneers naturally fell into a convenient well-worn

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path. For prior centuries, engineers had studied the effect of the wind on structures and on windmills and sails, and they had reduced their results to a ratio expressed as the force per unit area. In aerodynamics, such a ratio is found in practically all formulas involving lift or drag. Referred to as the wing loading, and given in a pound per square foot unit, it is an important figure in aircraft performance. Students of natural flight have sought to use this as the parameter which would aid in the solution of their problems.

Birds vary greatly in wing loading, ranging from a high of about 2.5 pounds per square foot down to about 0.2 pound per square foot. Insects have wing loading of about 0.02 pound per square foot.

From studies of natural flight have come certain fairly general agreements. For example, it is found that, when other factors remain the same, an increase in wing loading is accompanied by an increase in frequency of wing flapping. Furthermore, it appears that if two natural flyers have the same wing loading, the heavier bird with the larger wings will have the lower frequency of beating. As may be detected, there is a contrary note in these two accepted and observed facts. The insect has a very light loading; apparently his wing vibrations should have a low frequency. But we know that the frequency is very high. Accordingly, then, the second factor of absolute weight is evidently quite important. It is this situation which has militated against the wing loading as a satisfactory parameter for explaining the relations sought. Attempts have been made, in other directions, to find a suitable parameter.

One of the obvious uses of such a relation would be the possibility of intelligent speculation on the design of large-scale, beating-wing aircraft. Aircraft constructed according to principles which such a relation suggests would be powerful tools of research. One of the early formulas devised for this purpose, that of José Weiss,[43] was called to my attention by Captain Walter S. Diehl. Weiss did not attempt to derive an expression relating weight, wing area, and frequency of beating wings, but was content to establish a connection between weight of the bird or aircraft and its wing area. Weiss's parameter takes the mathematical form:

$$K = P/S^{1.33}$$

where K represents a constant for each different type of flying structure, about 8 for the ordinary bird;

(Continued on page 52)

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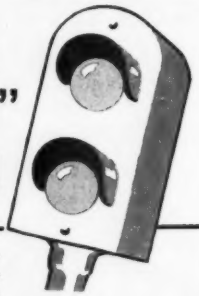

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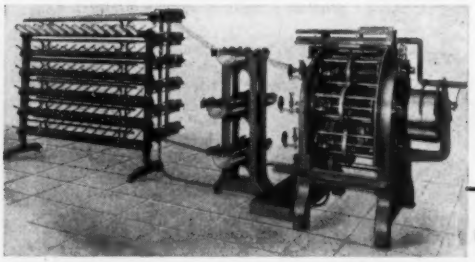

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NATURAL FLIGHT

(Continued from page 51)

P is the weight of the structure, in kilograms; and

S is the surface of the wing, in square meters.

It will be noticed that the wing area does not enter into this relation linearly but inversely as a four thirds power; Weiss explained the exponent as required to account for the volume of air attacked by the wing.

In the experiments of Alexander Jordanoglu, previously mentioned, the flight performance is checked against anticipated performance, based on a relation developed by Antoine Magnan.[9] Magnan related wing surface and beat velocity to the lift of the flyer according to the relation:

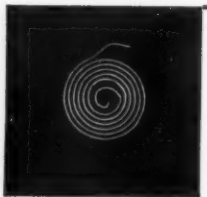
$$L = KSV^2$$

where L is the lift or weight of the flyer in kilograms;
K is a constant, which is about 0.066 for insects;
S is the wing surface in square meters; and
V is the beat velocity in meters per second.

In an attempt to derive a formula which would comprehend more of the important variables, the author struck off in a radical direction. Two concepts suggested the approach.

The first is that of the "sweep area." Ludwig Prandtl,[32] one of the great classic aerodynamicists, suggested this concept in the early days when the exact relation between biplanes and monoplanes was an important question. We have seen that one explanation of lift is that it is due to a reaction caused by thrusting downwards a certain mass of air. Prandtl showed that the volume of air affected by the passage of an airplane during a given time interval could be represented by a cylinder whose length was equal to the distance traveled, and whose diameter equaled the wing span. He called the sweep area the circular area of a diameter equal to the wing span.

The second concept has been mentioned previously; that of regeneration. One of the difficulties in the way of considering this concept has been the lack of any reasonable theory which might account for such a phenomenon. In studying that matter, the work of M. J. M. Hill[44] on the spherical vortex came to the author's attention. The ball vortex formation bears a close resemblance to the ordinary smoke ring of the cigarette or cigar smoker. In theory, and nearly in practice, it has the property of allowing a discrete



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mass of air to move through the surrounding atmosphere without loss of its identity and at only a small loss in energy. It would appear, therefore, to be the very sort of energy vehicle which the regenerative theory demands. The swept volume of air which had formerly been left as an energy-bearing wake now rolls up and accompanies the vehicle in an airy imitation of a caterpillar tractor. On this basis the following formula for frequency of beating was developed in 1945:

$$F = 4W^{0.833}/M$$

In this relation, F represents the frequency of wing beating in strikes per minute, W is the weight of the bird or aircraft, and M is the weight of the ambient air contained in a sphere whose diameter is equal to the wing span. For sea level conditions, it may also be written:

$$F = 100W^{0.833}/b^3$$

where b is the span of the aircraft in feet; W in pounds. The weights may be measured in any convenient units since W and M have the same dimensions.

This relation has been checked against large numbers of bird, bat, and insect observations. Its success in predicting missing variables is as good as may be expected in biological matters. For the insect it is progressively further in error as the size of the insect diminishes; and this fact suggests that perhaps another variable should be introduced. The matter is still under study. It is well to note, however, that the range of reasonably close predictions cover weight ratios of three million to one. The weight range from a large bird to the smallest possible airplane is only of the order of 30 to one. May we now extrapolate to the airplane scale? Only time and experimental determination can supply the final answer.

If we succeed, and get into the air with flapping wings, certain problems are going to arise. The anti-aircraft gunners will have to revise their advice: "If it flaps its wings, don't shoot." Blear-eyed duck hunters near the naval air stations had better be sure, too; the duck may fire back.

Engineering Construction

If we inquire as to the engineering practicability of natural flight theories, we find that many notable investigators have reached this point and despaired.

(Continued on page 54)

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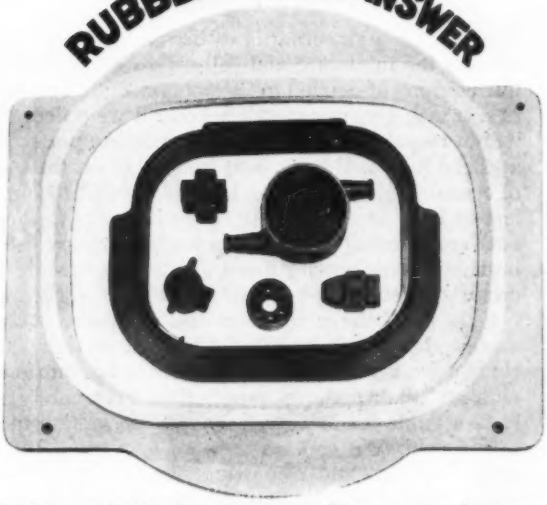

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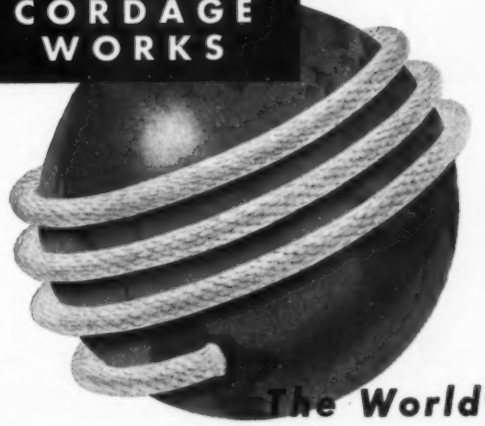

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NATURAL FLIGHT

(Continued from page 53)

The task of engineering is to design, construct, and operate the miniature and full-scale models and the test equipment needed to validate or refute our theories. It may give our morale a boost if we reflect that within recent years we have succeeded in perfecting artificial hearts, kidneys, and lungs; but on the basis of considerable experience, I would say that the problem at hand is, if anything, more difficult. It would not be surprising to see a new and amazingly useful branch of engineering grow here, even though the original object of the search is never attained.

I do not believe that, on this occasion, success awaits the time-honored method of making one change at a time. Rather do we seem to be confronted with an "all or nothing" proposition. Fortunately, we have a guide for any engineering construction to be undertaken. We can, as it were, capture some of nature's design and reconstruct the textbook. Man's duplication of some of nature's engineering is fraught with problems sufficient to shake the bravest heart. For example: "throw away the micrometers," "it can be done without metals," "carry parallel compression loads on one member wherever possible," "use members of selected elasticity to carry tension loads, the tension component of bending loads, and torsional loads, with the help of a compression member," "design to spill excessive aerodynamic and hydrodynamic loading," "keep the density fairly high," and "loosen up the joints" appear to be maxims of nature's engineer; but man will have an exceedingly difficult time in following the advice in the textbook.

Nature's school encourages athletics; flying for fun in hurricanes is one of the diversions. The postgraduate department features a study of the nonmetallic, nonpressure volume engine. If you tire of the classroom activities, a glance out the window may show you one of the professors on his day off, landing on a telegraph wire. Coeducational strolls on the campus may be interrupted by the presence of Dean Flittermouse, who has the strange habit of doing his nocturnal take-offs and landings in the upside-down condition. Perhaps it is this which makes his students call him the bat.

We have not a finished business here, but the courage and persistence of the hundreds who have pushed our knowledge this far are pledges of the interest and promise of natural flight. Numerous examples show that we can profit from details. Can we grasp the whole? Can we use it?

Gilbert K. Chesterton, master of the paradox, would find himself very much at home in this field. The competent, specialized theoreticians have often been overwhelmed by the inescapable mass of real detail while the practical masters of detail have been mesmerized by an isolated theory. The genius of intellect and the genius of matter await the situation which can happily unite them. As the arts and the sciences mature, there arises greater need for an over-all guiding philosophy. Progress will need a marriage of these diverse talents. A remark of Garrett Birkhoff in his

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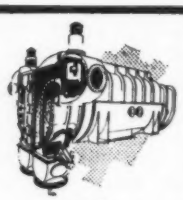

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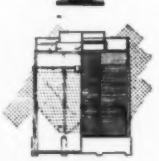

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NATURAL FLIGHT

(Continued from page 54)

book, *Hydrodynamics,* is worth quoting: "I believe that the resourcefulness and ingenuity of the human mind in combining these methods is vastly underestimated in all existing formal theories of mathematical and physical logic."[45] He was referring to induction and deduction, but it may well apply here. We may extract from him also a quotation which fits the entire problem: ". . . science was not built by timid or faltering hands. Let us move boldly forward, seeing what kind of edifice one can construct on these somewhat insecure foundations."[46] Perhaps an elastic structure is perfectly suited.

There exists, the world over, an incalculably large potential of freight and passenger traffic which cannot be tapped by aircraft as we now know them. Furthermore, all design-trend studies show we are moving ever further from serving this neglected area. The expert of the highly developed railway and transport age of the 1890's could hardly foresee the potential which a half century of motor land transport could not only release but produce *de novo.* The same applies to many air experts today. The demands of the more undeveloped areas for cheap bulk cargo and low-rate, low-speed passenger traffic are almost beyond comprehension. The popular personal airplane is nearly as far away as when the Wright brothers first flew. There are fewer such airplanes than small yachts. We sometimes forget that the automobile and the airplane are practically of an age. What a difference in numbers and practical workaday utility there exists between them!

We owe it to our own generation and to the future to seize upon this problem and benefit from the spoils which the conquerors of nature's citadels have inevitably received in reward.

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GOOD NEIGHBOR POLICY

(*Concluded from page 20*)

sion to bear on the larger problems of the day. The report further suggests that Harvard and M.I.T. should extend their collaboration. It says: "In areas where they are both active, they should compete vigorously and frankly in the spirit in which there is competition in science generally. . . . In areas where they supplement one another they should collaborate." The report recommends continuation of the present arrangement between Harvard and M.I.T., whereby a graduate student in either school may pursue courses at the other with credit and without the payment of additional tuition. And it recommends closer liaison between the faculty members of the University and the Institute. The chairman of the committee which drew up this report was Vannevar Bush, '16, whose close association with M.I.T. is well known. But what may not be as well known is that Dr. Bush is one of the few graduates of the joint school, having received the degree of doctor of engineering in 1916 from both M.I.T. and Harvard.

And so we come to the good-neighbor policy of today which has been extended and strengthened by President Conant and by my chief and predecessor, Karl T. Compton, chairman of the M.I.T. Corporation. We see collaboration taking place freely and spontaneously along a wide front. Graduate students at Harvard take courses at M.I.T. without the payment of additional fees; and M.I.T. students, in about the same numbers, take advantage of the same privilege at Harvard. In the sciences, the departments of the two institutions come together for frequent joint seminars. There are numerous joint research projects, especially in the field of medicine. In World War II, M.I.T. was the center for radar research and development, while Harvard, appropriately, was the center for radar countermeasures. More recently the two institutions have pooled resources to undertake certain important studies for the government in the present emergency. Altogether there is a constant process of cross-fertilization, of faculty members voluntarily working together because they find it desirable to do so, which is much better than being regimented into doing so. To put it into geographical terms, is there along three miles of any river in the world a comparable commonwealth of scholarship and of research resources as we have along the Charles?

The author acknowledges gratefully the able collaboration of Miss Frances L. Van Schaick, research assistant at M.I.T., in the preparation of this article.

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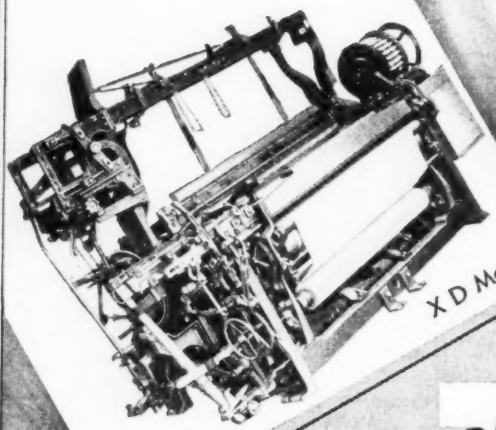

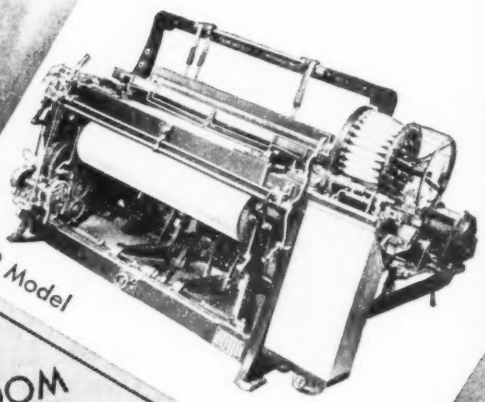

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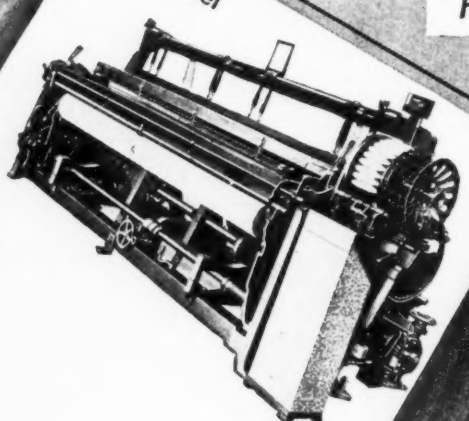

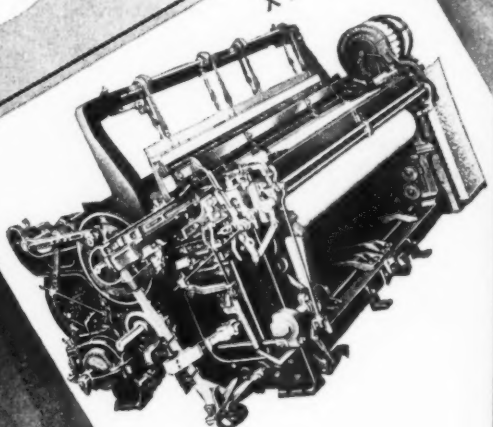

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